

PRACTICAL HANDBOOK SERIES

radio control for modellers

R. H. Warring



Radio-controlled models are the modern hobby interest. You can fly your own aeroplane, drive your own powerboat, helm a racing yacht, or race or rally cars at minimal cost and at no personal risk! And modern radio-control sets for models are easier to operate than a domestic radio. They do not need tuning or other adjustments. There is no 'wiring up' to do. The various units which go to make up a complete installation are prewired, ready to plug together, switch on — and go! But it is not quite as simple as that. There is an almost bewildering selection of radio-controlled equipment available, at prices ranging from under £20 for a 'Combo' up to over £400 for a sophisticated 'complete outfit'. You can easily spend a lot more on equipment than you need to do; or equally find that 'minimum cost' equipment has no chance of providing you with what you really require.

This book gives you all the answers you need to select, install and operate radio-controlled models and achieve satisfying, rewarding results. It shows how to select the right type of equipment for the type of model you have in mind (not buying more, or less, performance than you actually need) . . . how to install your radio equipment in model aircraft, boats, cars (requirements are different) . . . and how to operate radio-controlled models successfully. There is information on inexpensive ways of operating additional controls . . . even a chapter on aerial photography using radio-controlled models.

A thoroughly practical book throughout, written in non-technical language by an author with vast experience in R/C models

(continued on back flap)

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PRACTICAL HANDBOOK SERIES

*RADIO CONTROL
FOR
MODELLERS*

by

R. H. WARRING



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CONTENTS

<i>Chapter</i>	<i>page</i>
1. Introduction to Radio-Control Systems	7
2. What Type of Model?	17
3. How Many Channels?	24
4. Transmitters	28
5. Receivers	37
6. Servos	43
7. Choosing an Outfit	54
8. More Sophisticated Outfits	62
9. Installing and Connecting-Up Controls	74
10. Saving a Servo or Channel	91
11. Aerial Photography with Models	98
12. Operating Radio Controls	109
13. Batteries	115
14. Servicing and Repairs	121
<i>Appendices</i>	
I. Legal and other Requirements	124
II. Model Radio-Control Frequencies	125
III. 27MHz Spot Frequencies	126
IV. U.K. Frequencies and the Future	128
<i>Index</i>	130



Chapter One

INTRODUCTION TO RADIO-CONTROL SYSTEMS

THE MODERN RADIO CONTROL OUTFIT is designed to be as fool-proof as possible. It requires no adjustment since it is set up and pre-tuned by the manufacturer. No wiring up is required since separate units that have to be connected together are prewired and fitted with plug or socket end connections. Thus leads from a *servo* terminate in a plug which is pushed into an appropriate socket in the receiver; and a separate wiring harness, incorporating an on-off switch, plugs into a prewired battery or battery box at one end, and into the receiver at the other.

The whole system can often be demonstrated as working while still in its original box, merely by plugging in the appropriate connections and switching on the transmitter and receiver—but remove the transmitter and fit the aerial first. This is one general rule to remember. Do not operate the transmitter without its aerial being fitted. On some sets this *could* overload the output circuit and damage some of the internal components (transistors).

Another point to remember when 'testing' a set in its original box, or after purchasing it, is that the batteries are likely to be in a state of near-discharge. So take the first opportunity you can to recharge both the transmitter and receiver batteries.

No knowledge of electronics is required to get a radio-control outfit working, and wrong connections are 'impossible'. A foolproof system, whereby you rely on the integrity of the manufacturer, has virtually been achieved. The reliability of modern radio-control outfits is also very good, but Murphy's law which states that "if something can go wrong, it will" still applies. The usual cause of failure to operate properly is simply human error, e.g. trying to operate with run-down batteries or damaged plug prongs. The latter are usually very small and delicate and easily bent out of shape or even broken off, and although they are spaced so that they cannot be plugged in the wrong way round, some clumsy modellers can even achieve this. Sometimes a crystal is fitted in the receiver which does not match the transmitter crystal. Even—and this happens surprisingly often when the radio is

installed in a model—forgetting to switch the receiver on is not an uncommon occurrence.

The above, of course, applies specifically to ready-made units. The days when a modeller built his own radio gear from components is long past. Nearly every radio modeller buys a proprietary outfit. A limited number of firms, however, produce transmitters and receivers in kit form, which may appeal to modellers with some experience in practical electronics. They can offer a saving in total cost, and properly assembled and wired up can give a satisfactory performance. Their chief limitation is that if the completed set does *not* work, usually the only answer is to return it to the manufacturers for checking and setting up. (Kit manufacturers normally offer this service).

Radio-Control Systems

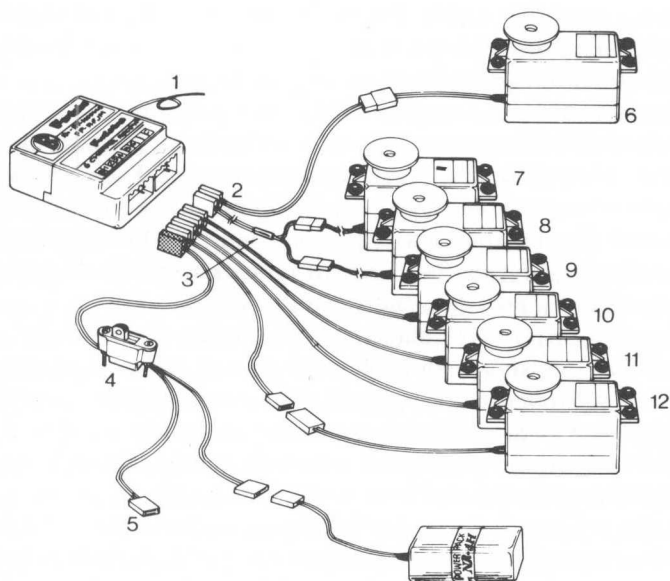
A radio-control system breaks down into three major components:—a *transmitter* (known as a Tx), a *receiver* (known as an Rx) and matching *servos*.

The transmitter includes an internal (rechargeable) battery or a battery box to take drycells. A separate battery is associated with the receiver. This can be a rechargeable (Nicad) battery, or again a battery box to take drycells. Possible combinations are:—

1. An all Nicad system (Tx and Rx batteries both of rechargeable type).
2. An all-drycell system (using dry cells for both the Tx and Rx batteries).
3. Drycell Tx, Nicad Rx (referring to the types of batteries used in the transmitter and receiver, respectively).
4. Nicad Tx, drycell Rx.

The only real justification for an all-drycell outfit is a saving in initial cost. A set of drycell batteries costs less than one-tenth that of equivalent Nicads, making the initial cost of the system much lower. However, this is only a temporary saving since the life of drycells is quite limited and so they have to be replaced regularly. Nicad batteries are rechargeable.

Normally the options available are an all-Nicad Tx and Rx or an all-drycell Tx and Rx. Because of the limited battery life of drycells, a drycell-Tx, Nicad-Rx combination would be preferable to an all-drycell outfit for working more than two servos (i.e. a 3-channel or 4-channel Combo). The other alternative combination of a Nicad-Tx, drycell-Rx has no advantages at all and is seldom, if ever, used.



1.1 Plug-together connections are standard on all modern radio-control outfits. This shows a 6-channel receiver with seven servos (two are connected in parallel for aircraft landing gear operation—one servo for the main wheels and another for the nosewheel)

- | | |
|-------------------------|-----------------------|
| 1. Antenna wire | 7. Landing gear servo |
| 2. Extension cord | 8. Landing gear servo |
| 3. Landing gear adaptor | 9. Rudder servo |
| 4. Power switch | 10. Throttle servo |
| 5. Charging jack | 11. Elevator servo |
| 6. Flap servo | 12. Aileron servo |

Combos and Complete Outfits

A transmitter with a matching receiver is known as a *Combo*. A complete working system then needs the addition of the required number of servos. Just as the receiver must match the transmitter, the servos must also match the receiver. Thus manufacturers produce transmitters and receivers and servos to match, often with a choice of different types of servos (just as a camera manufacturer produces a range of lenses to match a particular camera body).

Some manufacturers advertise complete outfits (i.e. a Tx, Rx and appropriate number of servos to go with it). Others offer Tx-Rx Combos, with options of different types of servos to go with them to

RADIO CONTROL FOR MODELLERS

make up complete outfits. Prices quoted for *Combos* are therefore much lower, as the price of servos is not taken into account. But servos still have to be bought to build up a complete outfit.

As a general rule, a *complete outfit* comprises transmitter, receiver and servos of the same make. Servos of one make are not likely to work properly, if at all, with a Combo of another make. There are exceptions. For example, the Reftec Tx-Rx Combo has been designed to work with any Futaba servo. Also some individual makes of servos (usually special types) are designed to work with all conventional designs of *positive pulse digital proportional* Combos.

This introduces two technical terms. Forget 'positive pulse' and 'digital' as this simply describes the type of the working circuit. 'Proportional' refers to the response of the control system. All modern radio control is proportional, meaning that any movement of the control stick on the transmitter is translated into *proportional* movement of the servo operated by that control channel.

This is realistic 'full size' control, just as the movement of the front wheels on a car follow exactly the movement of the steering wheel, or the control surface of an aeroplane follows the movement of the joystick.



Example of a proprietary range of 'Combos' or Transmitter-Receiver combinations in 2-ch, 3-ch, 4-ch and 6-ch versions.

Operating Frequencies

Again the modeller need not concern himself with the operating frequency of his radio control system since this is a pre-set feature, except for the facility to change *crystals*. By law, radio control systems for models can only be operated within specific frequency bands in the U.K.

Actually *three* frequency bands are now available in the U.K.: 27 MHz, 35 MHz and 459 MHz. Almost all current equipment uses the 27 MHz band. 35 MHz is a new frequency band recently made available (1981). The 459 MHz band is UHF (ultra high frequency), which is technically more difficult to work with. Different frequencies are in use in other countries (*see* Appendix II), but it is illegal to operate on such frequencies in the U.K.

Frequency of operation is controlled by a crystal in the transmitter (Tx crystal) and another in the receiver (Rx crystal). These crystals stabilize transmission and reception respectively, at a precise frequency. The available bandwidth is such that a number of different 'precise' or *spot* frequencies can be utilized. This makes it possible to operate several transmitters simultaneously on the available band, each using a different spot frequency, without interfering with one another (*see* Appendix III). A receiver will only respond properly to a transmitter with a matching 'spot frequency' crystal.

Interchangeable Crystals

To take full advantage of this, transmitters and receivers are fitted with plug-in crystals which can be removed and replaced by crystals of a different spot frequency. Thus if modeller A and modeller B both turn up at the same site with sets fitted with 'red' spot crystals, say, only one will be able to operate at a time unless A or B changes his Tx and Rx crystals to a different 'spot' frequency. Then they can both operate simultaneously without interfering with each other.

Tx and Rx crystals must always be charged as a *matched pair*, as identified by their colour coding (Appendix III). It is actually the Tx crystal which determines the 'spot' frequency on which the set works. The Rx crystal frequency is slightly different (usually about 45 kHz lower). This is merely a technical feature of the *superhet* principle on which all radio receivers work. If Tx and Rx crystals are 'mixed', e.g. a red crystal fitted in the Tx and blue crystal in the Rx, the set will not operate. (If the mixed crystals are close together, e.g. red used with orange/red, the servos may judder or partially respond to transmitter signals, but they will not work properly).

RADIO CONTROL FOR MODELLERS

AM or FM?

Originally all model radio-control Combos worked on an *amplitude-modulated* (AM) transmitter signal. More recently sets have been produced working on a *frequency-modulated* (FM) transmitter signal. This is similar to domestic radio broadcasts which are transmitted both in AM and FM, but in the case of radio-control units a Combo is designed to work on AM *or* FM—not both, as with many domestic radios.

FM working requires a more complex detector circuit and crystals with closer tolerances. This makes an FM Combo more expensive than an AM Combo. The performance of FM is somewhat superior. The signal is 'sharper', and is less prone to interference by other FM signals. This does not make the FM receiver immune to interference from AM transmitters working on the same spot frequency. In other words, the necessity to operate on a spot frequency not being used by another modeller still applies.



Additional 'working' features are a great attraction on scale models—such as the water cannon on this fire-fighting ship.

The superior quality of FM performance over AM is far less marked with radio-control Combos than it is with the reception of domestic radio broadcasts. Thus whilst many manufacturers now offer FM versions of their 27 MHz Combos, AM Combos continue as the major (and cheaper) type.

UHF

Very little radio-control equipment at present is available for the ultra high frequency (UHF) or 459 MHz band. In this system circuit design requirements, and crystal stability in particular, are much more exacting. As a result a UHF Combo is much more expensive.

The main advantage of UHF working is that it is completely free from interference signals which commonly appear in the 27 MHz band, other than model radio signals. A common source of 27 MHz interference is the radio and operation of 'Citizens Band' walkie-talkies; but there are also other *legal* users of the 27 MHz band.

Even the UHF band allocated for model control use is not entirely free from interference problems. This band is shared by some other services, but it is easier to provide interference protection with filters with UHF than in the 27 MHz band.

Channels—and what they mean

A Tx-Rx Combo is also described by the number of signal *channels* it provides. This simply describes the number of servos it will work. Thus a 2-channel (usually written 2-ch) Combo can signal *two* separate control commands on its transmitter and its matching receiver will accommodate *two* separate servos plugged into it. Similarly a 3-ch Combo will work three servos, a 4-ch Combo will work four servos, and so on.*

Each servo can be controlled quite separately, and simultaneously with the other servos if necessary. Extension of control coverage

* Strictly speaking, the description should be 2-*function*, 3-*function*, etc, defining specifically the number of *controls* operable. In the early days of multi-channel radio using reed banks it needed two *radio* channels to operate one control, (e.g. one channel for signalling 'right' rudder and another channel for signalling 'left' rudder). For some time after *proportional* radio appeared a similar description was applied by certain manufacturers (notably Grundig in Germany), where a 2-*function* (proportional) radio was described as 4-*channel* (and 3-*function* as 6-*channel*, etc). This practice is now largely discarded. Thus with all proportional radio the description 2-*channel*, 3-*channel*, etc. is nearly always used, with the understanding that every single channel provides complete operation of a single control.

beyond 4 channels does not necessarily mean that these additional channels will provide *proportional* controls. On some transmitters these may be simple on-off controls where the servo runs to a limit position when switched on and stops, and returns to its original position and stops when switched off. This type of switched control channel would be used to operate a retractable undercarriage on an aircraft, for example.

Technically a Combo offering both proportional controls and one (or more) non-proportional controls should be specified by two numbers separated by a + sign. Thus a 2+1 Combo would provide two proportional control channels plus one non-proportional (on-off switching) control; or a 3+1 Combo, three proportional controls and one non-proportional control. This practice is no longer widely followed, especially for Combos offering more than four control channels. Thus a particular make of 6-ch Combo may, in fact, have only 4 proportional controls plus 2 non-proportional controls (i.e. 4 + 2; or perhaps 5 + 1). This may be only evident from a study of the specification, although an immediate clue is the type of control on the transmitter to operate the channel. A simple on-off switch would imply a non-proportional control; and a stick or slider a proportional control.

Channel outputs are identified by the servo socket positions on the receiver. If not marked, channel 1 is usually next to the battery plug position, then channel 2 and so on. The allocation of *transmitter* controls is not standardized, but can readily be checked on a 'try-and-see' basis. See the separate chapters on 'Transmitters' and 'Receivers' for more detailed information on this point.

Extras Required

Normally a Combo as purchased will include wiring harness, 1 pair of crystals, matching frequency pennant and everything else needed to get operational, except for dry batteries in the case of an all-drycell Combo. Nicad combos will normally be complete with Tx and Rx batteries and a battery charger. Servos are additional items needed to build up the complete outfit; these are normally supplied with mounting accessories.

Basically, therefore, the only extras which need to be bought are dry batteries (for an all-drycell outfit only); and additional crystals for operating on different 'spot' frequencies when required. The latter are not essential, but they are a worthwhile extra and if purchased at the



Ultra High Frequency (UHF) radio sets are much more expensive to produce and limited in the numbers made. The distinguishing feature is the very much shorter transmitter aerial.

same time as a complete outfit a full set of crystal pairs can often be obtained at a reduced price.

In the case of 27 MHz sets, a normal set is six pairs of crystals, enabling working in six different 'spots' in the 27 MHz band. Some sets may be suitable for working at 'split' frequencies, i.e. midway between the 'spots'. In this case up to 12 pairs of crystals may be used. A point to remember, however, is that sets operating on split frequencies *can* interfere with other sets designed for broader separation

(i.e. only six 'spots') and operating on either of the two adjacent frequencies.

A greater number of spot frequencies for operation are available on the 35 MHz band and the 459 MHz UHF band.

Rules and Regulations

Prior to 1981 a *licence* was required to operate model radio-control equipment in the U.K. whether the equipment was being 'bench tested' or used in a model. This requirement has now been waived, i.e. a licence is no longer necessary.

The main regulations that apply govern the power of model radio-control transmitters (affecting only manufacturers of equipment) and the prohibition of *speech* transmissions on the allocated model radio-control frequencies.

A commonsense requirement—obligatory for all members of model clubs—is third-party insurance of models operated by radio control.

Chapter Two

WHAT TYPE OF MODEL?

WHAT TYPE OF RADIO-CONTROLLED MODEL are you interested in? That also rather depends on what you want to do, and how you came to be attracted to radio control in the first place. If you have seen R/C models on television, or read about them in magazines, you have probably got a glamorized impression of what can be done—*by* experienced radio-control modellers. And even if you have had some previous experience of modelling—say as an aeromodeller—you may be tempted to think that here is the complete answer to your modelling ambitions. Perhaps you look forward to owning a true-to-scale multi-engined model, or a helicopter, which you can fly safely under full control all the time.

Certainly that is possible, once you have *learnt* to fly by means of radio control and gained sufficient flying hours to be competent as an R/C pilot. That will probably mean starting with a basic R/C trainer and working up through two or three progressively more advanced models.

Tuition is Best

Much also depends on whether you have to operate as a lone hand or not—if you do, you will have literally to teach yourself to fly by trial and error. Almost inevitably that will mean a number of crashed and badly damaged models on the way. It is far better if you can start R/C flying under expert tuition. Many model shops offer such basic tuition for newcomers to the hobby. Model clubs normally have one or more experienced R/C flyers who are also prepared to act as instructors.

The advantage of tuition is two-fold. In the first place the model you have built can be checked out and test flown by an experienced R/C pilot. Anything wrong with it can be put right at this stage. So you start to learn to fly with a model you know is functioning properly. The other advantage is, of course, that initial responsibility for the safety of the model is in the hands of the instructor. He can take it off, hand control over to you when at a safe height, take-over immediately to correct any mistakes you make, and finally land the model safely. Also, with tuition available, you can safely *start* with a powered aircraft if you wish.

The best way a trainee pilot and instructor can work together is with a 'Buddy Box' system. Here both trainee and instructor have their own transmitter, connected by a 'buddy box' lead. By simply pressing a button on his transmitter the instructor cuts out his own transmitter so that any signals from the trainee's transmitter are effective. Conversely, by releasing the button, he can cut out the trainee's transmitter and control the model via his own transmitter.

'Buddy Box' Operation

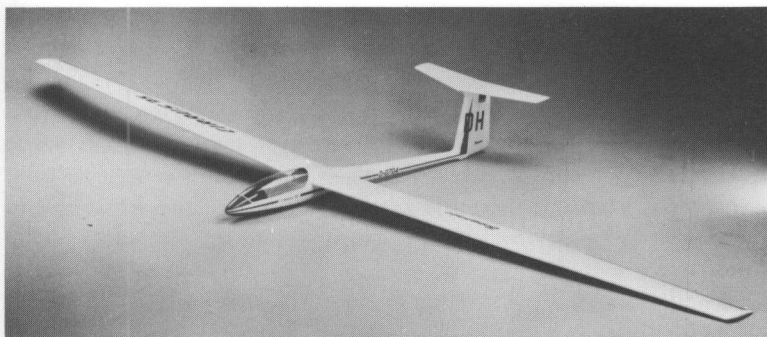
To work a 'Buddy Box' system the two transmitters must be compatible, i.e. of the same make and type *with* 'buddy box' facility. They do not necessarily have to have the same number of channels. Buddy-box switching on a 6-channel transmitter (the instructor's) may be effectively worked with a 4-channel transmitter of the same make and type. Not all 4- and 6-channel transmitters do provide 'buddy box' facility, though. So here is a point for a beginner to discuss when choosing his transmitter. If the possibility of tuition is arranged first, then the model shop or chosen instructor can recommend the right choice. At the same time the beginner should take similar advice about the choice of a suitable R/C trainer *model*. Some are excellent as trainers because of their docile and forgiving flight characteristics. Others, stated to be trainers, can prove relatively tricky to fly.

The lone hand who *has* to teach himself to fly is advised to start with a *glider* featuring rudder and elevator control. One suitable for tow launching ('bungee' launching) is best, as this can be flown from level ground. It should also be a trainer type with plenty of inherent stability. Starting with a slope soarer launched from the top of the hill will inevitably mean many, many trips up and down the hill to recover the model before the pilot has learnt the basic art of keeping the model well into the 'lifting' area above and slightly in front of the hill and being able to land it back near the starting point.

First R/C Power Models

The next logical step would be an *auxiliary sailplane* or a *lightly loaded* electric flight model.

The auxiliary sailplane is simply a glider with a pylon or nose-mounted engine of low power—just enough power usually to allow the model to climb gently. It only needs rudder and elevator control, and provides a gentle introduction to flying an R/C powered model.



Model sailplanes with large wingspans have an outstanding performance when radio controlled. Many require only 2-channel radio for elevator and rudder control.

On a larger auxiliary sailplane throttle control *could* be added to gain familiarity with the use of this control, but this is unusual.

The lightly loaded electric flight model is really a sailplane again, but powered by an electric motor. Again it is an 'underpowered' power model, so fairly easy to control. Preferably it should be large enough to accommodate 3-channel radio (the third channel being used for on-off motor switching); and lightly constructed so that it will fly reasonably slowly and climb reasonably well on the relatively low power output generated by electric motors.

These two requirements make the electric flight model far from ideal as a first R/C model. A lightly constructed model is more easily damaged. A more robust electric flight model is inevitably heavier, flies faster, so reactions to control requirements have to be faster. It leaves less 'thinking time' to sort out piloting errors. The auxiliary sailplane, therefore, is a 'safer' proposition for a first R/C power model.

Radio-Controlled Trainers

Experience gained both in the installation of the radio-control system and using the controls properly in flight will be invaluable when it comes to the next model—a powered R/C trainer, with rudder, elevator and throttle control. It is best to start with rudder and elevator controlled by the same stick—the right-hand stick being a logical choice for a right-hander, or a 'throttle left' transmitter. The difference in flight characteristics will be quite startling at first! It will

be more heavily loaded, fly much faster, respond to control much more quickly—and be a lot more difficult to land safely! The tendency at first will be to over-control it all the time.

Anticipating that you will *not* learn to fly without crashing, build *two* identical models, both fitted with engines. If you install the radio gear properly it should survive crashes, so you can swap the receiver and servos from one model to another. Then you should be able to have one model serviceable for the next self-tuition session whilst the other is being repaired!

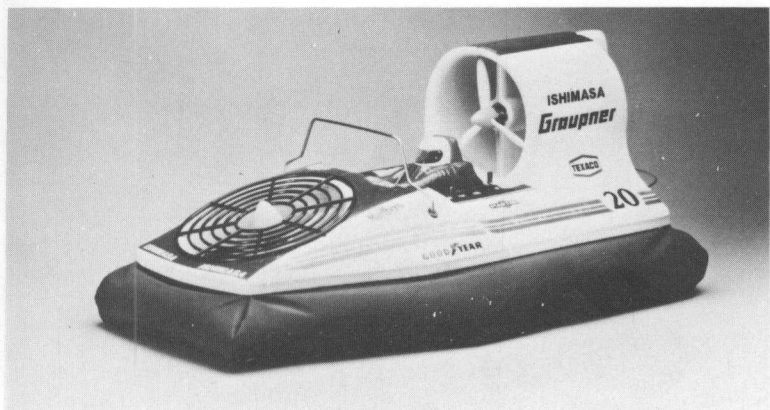
When, and only when, you have mastered the technique of flying on rudder, elevator and throttle you can advance to a similar type of model with ailerons. This will demand partly re-learning to fly all over again. Instead of the rudder, the ailerons are now the main *turning* control and have to be used in a different manner from that which you have become used to with rudder. Aileron turns are made by applying ailerons to roll the model into a banked attitude and then applying a little up-elevator to pull the model round into a turn. At the same time, once the right amount of bank has been reached, ailerons are eased off to prevent the angle of bank from increasing. A little *opposite* aileron is then needed at the completion of the turn to bring the wings level again, easing off the up elevator at the same time. It is the elevator control, in fact, which governs both the tightness of the turn and determines whether the nose of the model drops, stays level or rises during the turn.

Since turning always involves the use of both ailerons and elevator these controls need to be on the same stick. Rudder is now transferred to the other stick (together with throttle), i.e. to the opposite side to which you have been used to with a rudder-elevator-throttle trainer. So for take-offs, when you *need* to use the rudder to keep the model straight, you now have to re-learn that the rudder is on the opposite stick to which you are used. Apart from take-offs and landings, though, the rudder is little used as a control with a 'full house' model, except doing certain more advanced movements, e.g. in rolls, ailerons, elevator and rudder may be used simultaneously.

At all points along the line of a lone hand teaching himself to fly, expert tuition would be a greater advantage and worth travelling miles to find!

Radio-Controlled Boats

Radio-controlled boats, by comparison, are dead easy subjects,



A 2-channel radio controls this highly successful hovercraft model. It is powered by two electric motors.

especially electric-powered slow moving craft. The beginner can usually control them satisfactorily—if not competently—from the very first trip. And little or no harm is likely to occur through applying a wrong control movement at a particular time. Even complete radio failure is not likely to cause more than temporary embarrassment.

So, if you want to start radio control the easy way, an electric boat is probably the ideal subject. Just make sure that it is large enough to be 'seaworthy' under the conditions you want to operate it.

Faster engine-powered boats need more skill to operate safely, and properly. Because of their speed and rapid response to rudder movement 'thinking time' about what control to apply is greatly reduced. Control needs to be more instinctive, as is necessary with aircraft—something which will only come with practice. Operate at less than full throttle, except for occasional short straight runs, until you have developed a sense of instinctive control. It will still be a lot easier—quicker to master—than flying an R/C aircraft as you only have to concentrate on the one main control (rudder), and the model itself is—or should be—inherently stable and travelling only in one plane.

Yachts also need skill to sail properly under radio control, particularly when it comes to learning how to use the rudder moderately, not excessively, to hold a true course. They may be regarded as another generally safe type of radio-controlled model—which, even if something does go wrong—prove as safe as any free-sailing yacht of the same size or type.



Both electric and I/C engine powered cars are popular subjects for radio control, with proportional steering and motor speed/braking covered by 2-channel radio.

Radio-Controlled Cars

Radio-controlled model cars range from power toys with elementary steering control to 'proper' models and highly specialized designs for competitive racing. All have one thing in common. They demand fast reaction times to steer properly because of the relatively high speeds at which they operate. A 1/10 or 1/12 scale electric powered R/C car—about 12–14 in. (30–35 cm) long—may well achieve speeds in excess of 20 mph, or over 200 mph 'scale speed'. Engine-powered racing cars are larger (typically 1/8th scale), and may achieve speeds in excess of 35–40 mph (equivalent to a 'scale speed' of some 300 mph!).

Probably the main limitation to radio-controlled cars is finding a suitable place to operate them. Small electric cars can be operated indoors over most non-carpeted surfaces. The smoother the surface the better. But unless the area available is reasonably large and free of obstacles, collisions with walls, furniture, etc. will be difficult to avoid.

Outdoors, a smooth tarmac surface is as good as anything—but few tarmac areas *are* really smooth. Small electric cars with wheel diameters of only about 1¼ in. (32 mm) are operating at a disadvantage. Larger engine-powered cars are more at home on such a surface but, again, since they are faster, the effect of surface irregularities, ruts and small potholes can be just as marked.



Even motorcycles are a suitable subject for radio control—when designed with a special steering system. They need more practice to operate successfully than most other R/C models.

The best answer for an R/C modeller is to join a club specializing in this type of model. Not only will he be able to get help and advice from other enthusiasts, but the club will have access to suitable operating sites. Some, indeed, may have their own race tracks for R/C cars.

R/C car racing has, in fact, become an established and very popular sport, both for electric-powered cars (1/10th and 1/12th scale) and engine-powered cars (1/8th scale). Like all sports, considerable skill is required to become proficient at operating such models, and this will come with practice.

Join a Club

'Join a club' is good advice to anyone taking up radio-control modelling. Here it should be mentioned that model clubs are (almost) invariably specialized. That is to say, the modeller with an interest in R/C aircraft should join a *model aeroplane* club; one with an interest in model powerboats a *model powerboat* club; one with an interest in R/C yachts a *model yacht* club; and one with an interest in R/C cars an *R/C car* club. They are quite distinct entities, and model aircraft clubs may be further split. Some may only have a radio-control section, others may be interested only in R/C aircraft. And in addition there are separate clubs for powered R/C aircraft, R/C gliders, and even R/C helicopters in some areas.

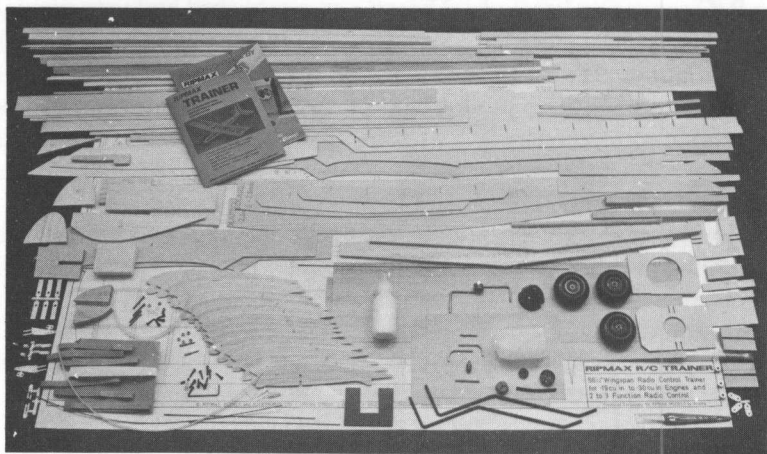
Chapter Three

HOW MANY CHANNELS?

TRANSMITTER-RECEIVER COMBOS are readily available offering 2,3,4,5 and 6 channels (i.e. 2,3,4, etc, separate controls available). More elaborate Combos may offer even more channels. Since the cost of a Combo increases with the number of channels provided, some sound background knowledge of how many channels are actually *needed* makes economic sense. And this will vary with the type of model involved.

Controls for models can be divided into two categories:

1. Essential for main function controls which are necessary for the control of a particular model.
2. Secondary controls or services which, whilst not necessary for full *functional* control, can further improve performance, or attractiveness, of the model. At this point it is best to consider radio-controlled model types separately.



The majority of radio-controlled models are built from kits, featuring numerous prefabricated parts. This is a typical aircraft kit with pre-cut wood parts, shaped wire parts, etc.

Glinters

A *2-channel outfit* (2-channel Combo plus 2 servos) is capable of providing good control of gliders, applied to *rudder* and *elevators*. Depending on the type of model, this can prove quite adequate for slope soaring, thermal soaring and reasonable aerobatic capabilities. Thermal soaring models, in particular, usually have high aspect ratio wings where the addition of ailerons can produce both structural and performance limitations. Thus, provided a high-performance soaring sailplane is *designed* for rudder and elevator control, it will usually perform more than adequately with just these two controls.

A *3-channel outfit* means that aileron control can be added—and this would be an essential feature for a fully aerobatic glider, for instance. Rudder, elevator and ailerons, in fact, provide full *functional control* coverage for gliders.

Strictly in the specialized high-performance contest-standard category, secondary controls which can prove useful and worthwhile are:—

- (a). Air-brakes or spoilers.
- (b). Water ballast dumping.

Powered Aircraft

Here there is a fairly clear distinction between model designs which incorporate a degree of automatic stability (usually high wing models with a fairly generous dihedral angle); and those with little or no built-in stability and which have to be 'piloted' all the time (most scale models with scale dihedral and fully aerobatic R/C models).

Full functional control of a powered aircraft demands the use of a *4-channel outfit*, providing rudder, elevator, throttle and aileron control. (This is known as 'full house'). The former type above can dispense with aileron control and so can be flown successfully with 3-channel radio. Most R/C trainers, in fact, are designed on this basis, and even without aileron control they can be capable of a good range of aerobatics. They are only an intermediate step on the way to full and proper control of powered aircraft, however.

Rudder, elevator, throttle and aileron control or 'full house' is *essential* on all high performance fully aerobatic models; and highly desirable on all types of scale models. However, to utilize 'full house' coverage properly the model must be designed to suit. Too generous a dihedral angle, for example, will make aileron control inefficient, or even ineffective. And as far as scale models are concerned, the full size prototypes are designed for 'full house' control coverage in the first

place, so anything less on a radio-controlled model is an undesirable compromise.

Secondary controls worth considering on high-performance models operated at contest-standard levels are:—

- (a). flaps
- (b). retractable undercarriage

This would indicate a 6-channel outfit as desirable, but not essential. Either of these services can be provided by a 4-channel outfit by 'coupling' (see Chapter 10) secondary services/controls which might be considered with a non-contest type model include:

- (a). Camera operation for aerial photography
- (b). Bomb dropping, parachute dropping, etc., for display purposes.

Here (a) should definitely be operated by an additional (separate) control(s) (see Chapter 11).

Powerboats

A 2-channel outfit provides *full functional control* for powerboats. The first and most important control is rudder. On a high-speed I/C engined boat, throttle control is just as essential. On slower, electric-motor powered boats, 'engine control' is more desirable than necessary. Simple on-off-reverse switching will be adequate, but full speed control will be more satisfying. High speed electric-powered boats or 'fast electrics' require both rudder control *and* motor control.

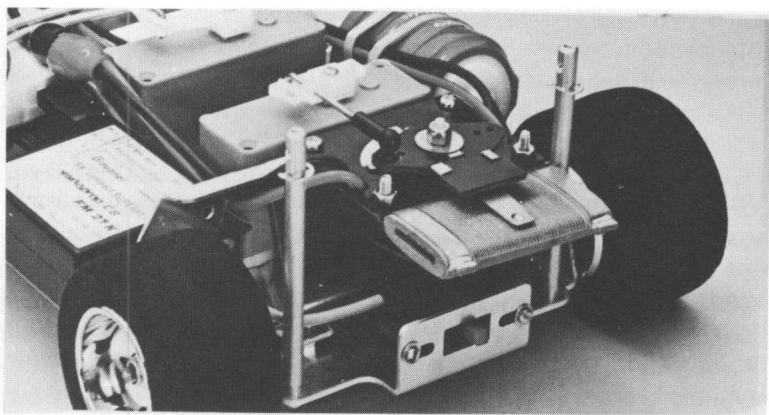
The latter should be *proportional* speed control—virtually essential for course steering or racing events. It also means more complete control of a fast boat which is highly desirable for improved relationship with other types of boat modellers using the same pond!

A further function worth considering on high-performance powerboats is independent operation of transom tabs for trimming purposes.

On other types of boats, particularly electric-powered scale models, additional functions are only justified for 'display' purposes, e.g. for operation of working features such as gun turrets, navigation lights, anchor winching, etc.

Model Yachts

Here a 2-channel outfit will again provide *full functional control* via rudder and sail adjustment (via a sail winch or other Sail Control Unit). There is no need to use a separate sail winch for the main sheet and jib sheet. One winch will handle both sheets adequately.



Radio installation in a model car is invariably cramped. Unit at the rear is a servo-operated speed controller for the electric drive.

The racing enthusiast, though, may well find the additional cost of a *3-channel outfit* more than worthwhile, using the third servo for independent fine adjustment of the jib sheet—or ‘jib twitching’, as it is called.

With these general guide-lines in mind, a study of Chapter 7 will make it easy to decide which is the best outfit to choose. It is important not to make a mistake when buying your first outfit as this can prove costly in the long run, as well as limiting the enjoyment you can get from operating radio-controlled models.

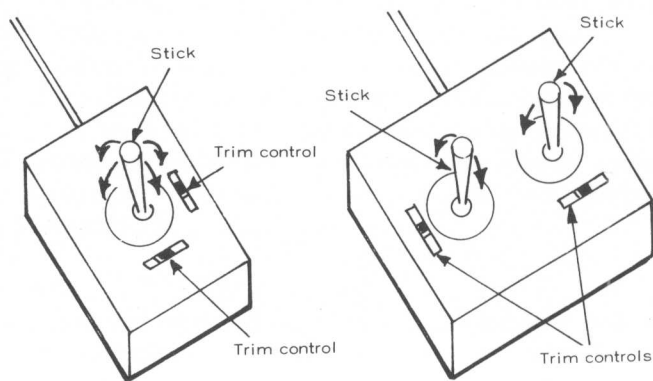
Chapter Four

TRANSMITTERS

VIRTUALLY ALL RADIO-CONTROL TRANSMITTERS take the form of a rectangular 'box' with the controls on one face. Proportions are designed so that it is easy to hold in the hands with controls easily manipulated by thumb or finger and thumb. The balance should also be comfortable, although most manufacturers make provision for fitting a neckstrap to all larger or heavier transmitters for more comfortable handling over longer periods of operation. Some manufacturers, too, stylize the case; others merely design it as a functional 'box'.

A telescopic aerial is standard, fitted to or through the top of the case so that it is angled towards the vertical when the transmitter is held in the normal way. (The more vertical the aerial is in use the better its radiation properties, and thus transmitter *range*). A transmitter should always be worked with its aerial fully extended for the same reason.

The usual form of control movement is a joystick (simply called a stick), either simply pivoted or universally pivoted. A simply pivoted stick is used for controlling one channel. A universally pivoted stick is used for controlling two channels, either separately or simultaneously. Thus a 2-channel transmitter could either have two separate



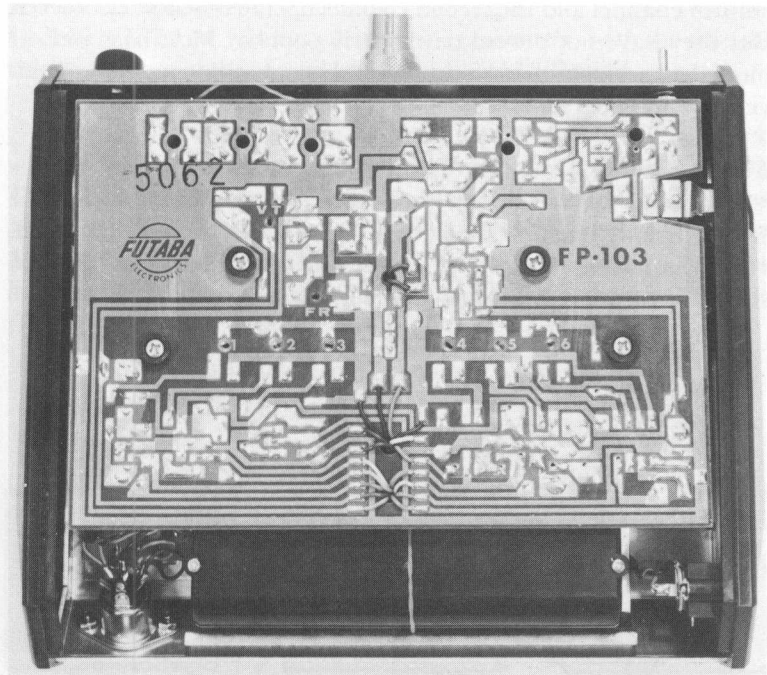
4.1 The two versions of a 2-channel transmitter

TRANSMITTERS

simply pivoted sticks or a single universal stick (Fig. 4.1). In the former case one stick movement would normally be up-and-down and the other side-to-side. (The actual stick movements are the same in this case; one stick is simply mounted at 90 degrees to the other).

Single Stick and Twin Sticks

There are advantages and disadvantages to both systems. The single stick provides one-hand control (stick held lightly between fingers and thumb) with straightforward simultaneous operation of both controls. This would be a decided advantage for control movements which may be *needed* simultaneously, e.g. rudder and elevator controls on an aircraft. The side-to-side movement would control rudder, with a little upward movement applied at the same time to provide elevator correction in the ensuing turn. On the other hand it would not be suitable for controlling rudder and sail winching on a yacht as an involuntary up or down movement when operating



Rear cover removed from a typical transmitter to show the printed circuit board. Reliability is high with modern circuits of this type.

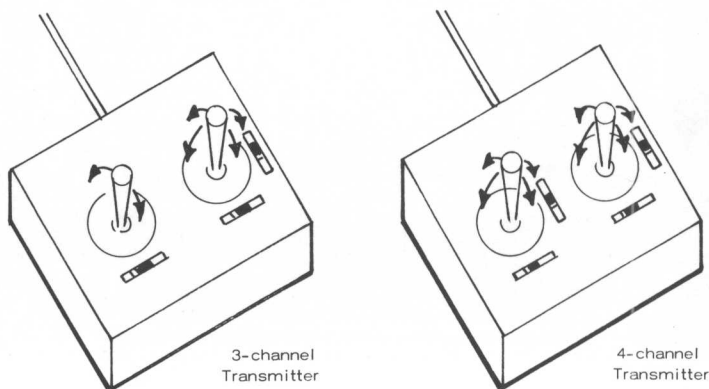
steering control could immediately alter sail trim. Here a two-stick layout would be better.

With powerboats or cars the option is more open. Stick movements are normally self-centering (i.e. the stick returns to its central position if released); but can also be ratchet-braked to stop in any position to which the stick is moved. Ratchet-braking on the up-and-down movement of a stick is normally used as a throttle control. It is not usual to find it fitted to a single-stick, 2-channel transmitter (i.e. both stick movements would be self-centering); but quite commonly found on a two-stick 2-channel transmitter. The latter type is then directly suitable for boats, using the self-centering stick for controlling rudder and the ratchet-braked stick for sail setting (on yachts), or motor control on powerboats.

'Wheel' steering would seem more logical for boats, and particularly cars. Transmitters are available with this feature, e.g. a 2-channel transmitter with a wheel instead of a stick for one (steering) control channel and the second channel operated by a stick or lever. But they have not proved particularly popular. Most boat and car modellers seem to prefer stick controls; and stick controls are universally accepted for aircraft.

Control Positions

3-ch and 4-ch transmitters invariably have two control sticks. One stick is simply pivoted (controlling one channel), and the other universally pivoted (controlling two channels). With a 4-ch Tx both sticks are universally pivoted (Fig. 4.2).



4.2 3- and 4-channel transmitters

TRANSMITTERS

Allocation of control channels to stick movements is purely arbitrary. Receiver plug-in points for servos may be marked Channel 1 (or Chan 1 or Ch 1), Channel 2, etc., starting from one end, next to the battery plug-in-point. Which servo to plug into which (Channel) socket to respond to a particular stick movement is not always stated. Some manufacturers allocate channel outputs to stick movements in different ways, but the usual arrangement is shown in Fig. 4.3.

Thus on a 2-channel Transmitter:

Right-hand stick side-to-side (or side-to-side movement on a single stick) is Channel 2.

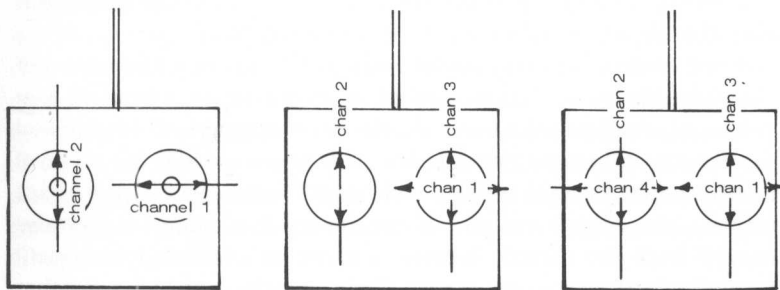
3-channel Transmitter:

Channels 1 and 2 as for a 2-channel twin-stick transmitter, with the up-and-down movement of the universal stick controlling Channel 3.

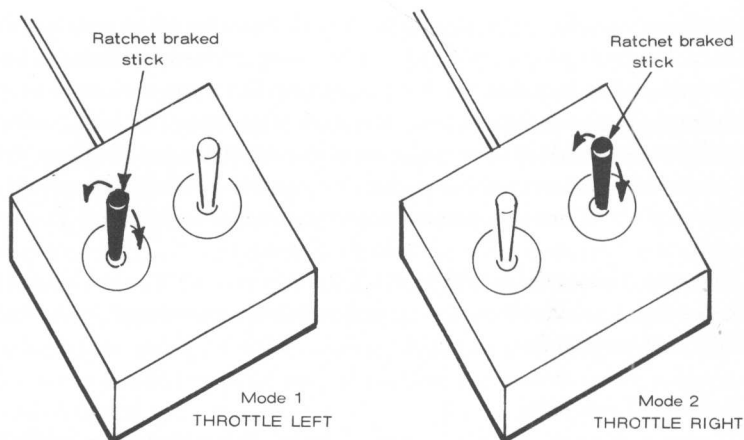
4-channel Transmitter:

Channels 1, 2 and 3 as for a 3-channel transmitter, with the side-to-side movement of the second stick controlling Channel 4.

Normally, as supplied, the up-and-down movement of one stick will be ratchet- or friction-braked to function as a throttle control. This stick may be mounted on the left-hand side, referred to as 'throttle left' or Mode 1; or on the right side, i.e. 'throttle right' or Mode 2 (Fig. 4.4). 'Throttle left' is the conventional choice, but left-handed operators (and some right-handers) may prefer 'throttle right'.



4.3 Typical channel allocation on 2-, 3- and 4-channel transmitters. This may vary with different makes



4.4 Mode 1 and Mode 2 transmitters

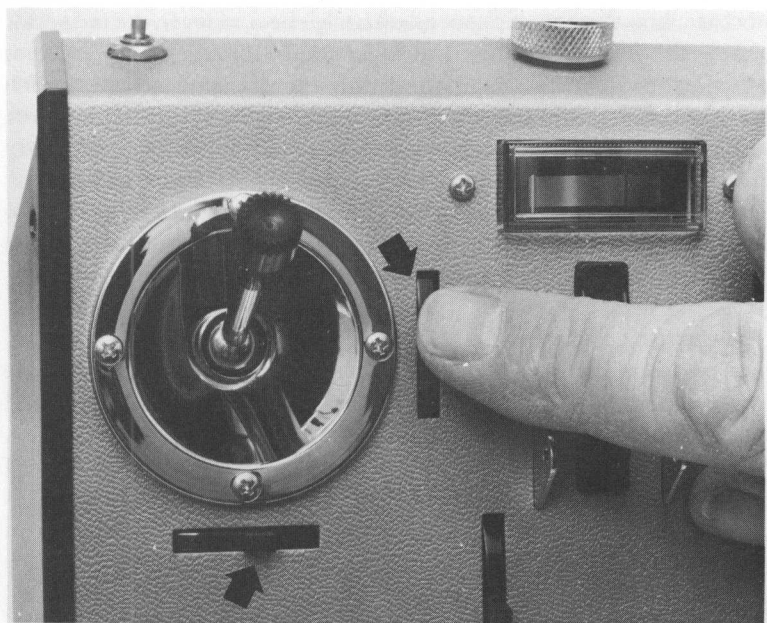
Trim Controls

All the main controls on transmitters are also normally associated with separate *trim* controls. The trim control takes the form of a small 'braked' lever or slider located underneath or alongside the stick position (Fig. 4.5). Each is designed to move in the same direction as its associated stick movement.

The object of the trim control is to provide fine movement adjustment. If, for example, the model does not fly or run straight with the rudder stick centred, the adjustment of rudder trim control can apply slight left (or right) rudder to compensate and trim out the model. In other words the actual neutral position of this control will be biased one way or another by movement of the trim control and stay in this biased position until the trim control is moved again.

Trim controls are very useful and can be used in other ways. For example, the throttle movement of an engine on an aircraft or boat can be adjusted for idling with the throttle *stick* right back (down) and the throttle *trim* right *forward*. This will give a normal full range of throttle control via the throttle stick. With the throttle stick right back (down), the engine will idle. If the throttle *trim* control is now also moved back the throttle linkage is given an additional movement beyond idle, stopping the engine. Thus an extra control function has been added.

To achieve this, of course, the throttle stop on the engine must be



4.5 Trim controls (arrowed) are located alongside their respective main control movements

backed right off and the idling position of the throttle lever set up by adjustment of the control linkage. There is also a variation on this scheme used by aircraft modellers to provide 'fast idle' (throttle trim forward); slow idle (throttle trim central); and engine stop (throttle trim right down).

Transmitters offering more than 4 channels may have their additional controls disposed in various ways. Additional proportional channels will normally be operated by a slider or thumbwheel-type control on the front or side of the case. Such a control would not normally have a separate trim. Non-proportional controls are normally operated by toggle or rocker-type switches, or even press buttons, on the top of the case. Some of the more sophisticated types of transmitters have even more elaborate control arrangements (*see* Chapter 8).

Other items normally found on the front of a transmitter are the on-off switch and a meter. The latter is normally only a simple voltmeter indicating battery condition, with the needle in the green

RADIO CONTROL FOR MODELLERS

sector when the batteries are adequately charged, or in the red sector when the battery voltage has fallen to an unacceptable level for satisfactory operation. Some transmitters may have a meter which indicates RF (radio frequency) output strength, which is a far more realistic parameter than battery voltage. Other transmitters may have meters indicating both battery voltage and RF output.

Other usual features of a transmitter are a detachable panel or opening for changing the Tx crystal; and in the case of a Nicad transmitter, a plug-in point for the battery charger.

Transmitter Accessories

Accessory items which some modellers may think desirable are transmitter cases, transmitter trays and muffs. Transmitter cases and transmitter trays are purpose-made to suit a particular transmitter. A Tx case is largely cosmetic, but also protects the transmitter itself from getting scratched or soiled. It serves little or no functional purpose, but may be considered a worthwhile accessory to keep an expensive transmitter in mint condition.

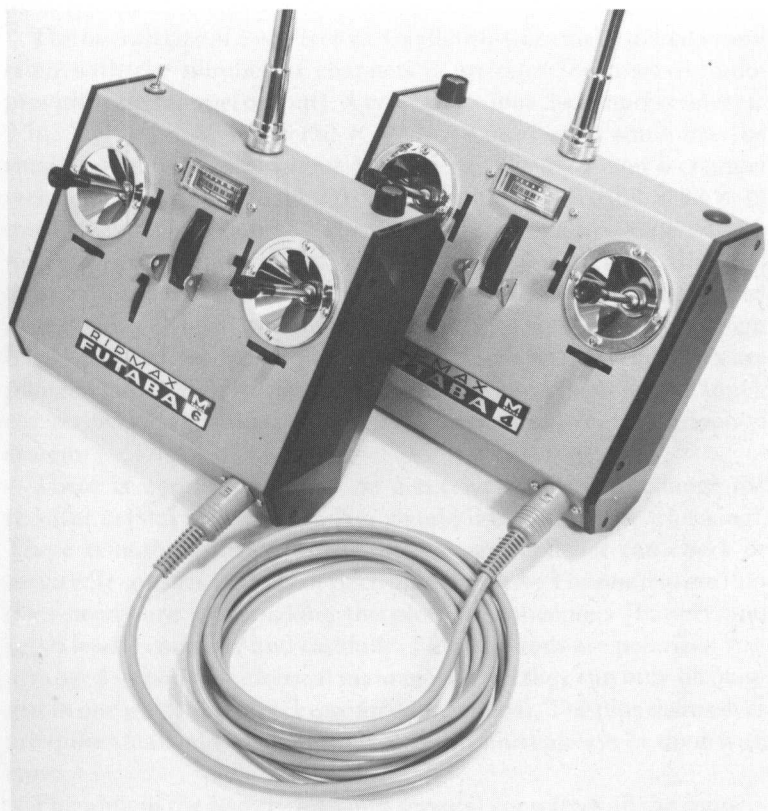


A fitted case can keep an expensive transmitter in 'mint' condition, but does not protect it against rain or dirt as sticks and trim controls must remain exposed.

TRANSMITTERS

A transmitter tray is designed for suspending by straps around the neck to take the weight of a transmitter and support it far better than a neckstrap alone can do. It leaves both hands entirely free to operate the controls. Without a tray, or full support by a neckstrap, the transmitter has to be *held* by both hands, one each side, with the sticks normally manipulated by the thumbs.

A transmitter tray has distinct advantages in eliminating fatigue when a transmitter is used continuously for relatively long periods and is particularly liked by R/C helicopter pilots. It is seldom used with other types of models.



Feature on some transmitters is 'Buddy Box' facility where instructor's and pupil's transmitters can be connected by a lead for instructor to take over control at any time. Very useful when learning to fly R/C aircraft.

RADIO CONTROL FOR MODELLERS

Muffs are designed for cold weather operation, permitting the operator's hands to remain enclosed in a warm 'glove' whilst at the same time giving freedom of finger movement to operate the transmitter controls. Useful for holding a metal case in freezing cold, but most modellers usually find rally-type car driving gloves almost as good and far less restricting.

In fact none of these accessories is essential for any transmitter. Smaller, lightweight transmitters (e.g. 2-ch and 3-ch types) often do not even have provision for a neckstrap, nor is this necessary for normal use. The larger and heavier the transmitter the more a neckstrap will be found useful, however.

Chapter Five

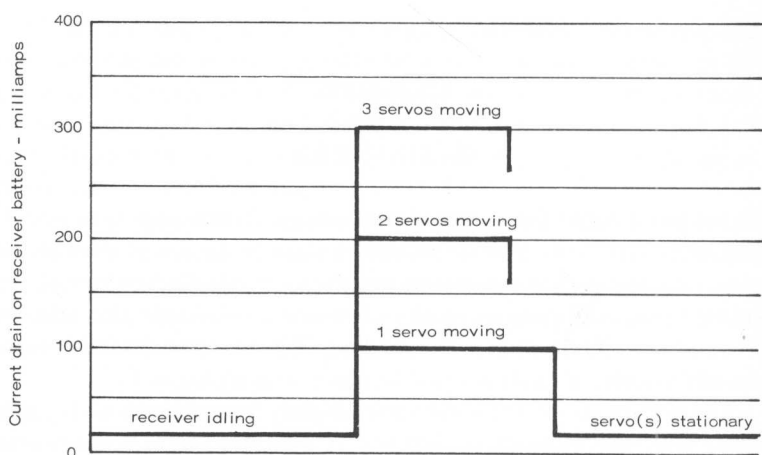
RECEIVERS

MOST RECEIVERS LOOK THE SAME: a small rectangular 'box' with a row of sockets at one end into which the battery lead and servo leads plug. All the receiver connections are internal. The only wire to emerge from the receiver itself is the aerial—a single thin plastic covered flex about 30 in. (76 cm) long. The receiver crystal is also usually visible, or easily accessible, again with a plug-in fit.

The overall size of a receiver varies slightly from make to make, and often with the number of channels it provides (each servo outlet provides one channel output). A typical size for a 2-channel receiver is 2 in. $\times$ 1¼ in. $\times$ ¾ in. (50 $\times$ 32 $\times$ 19 mm)—but some may be smaller—and weighing about 1¼ ounces. The 3-, 4- and 6-channel receivers are usually about 2½ in. $\times$ 1½ in. $\times$ ¾ in. (63 $\times$ 38 $\times$ 19 mm), weighing 2 ounces. There are the exceptions. One or two manufacturers produce receivers which are physically smaller and lighter, intended specifically for use in small aircraft. Also some manufacturers have adopted a different system of receiver design based on modules which plug together. Here separate modules are plugged into a basic receiver module to build up a 2-, 4- or 6-channel, etc. receiver, as required. This is a feature of the Grundig Variophon system.

There is nothing to adjust on a receiver (except to change the receiver crystal as required). Nor should it be opened for 'checking'. There is nothing inside which the average modeller can check or service. It consists entirely of electronic circuitry. The one feature that does need care is in making the plug-in connections (battery and servo leads) correctly and carefully. Plug positions are polarized (i.e. arranged in non-symmetrical manner) so that they can only be plugged in one way (the correct way for connections). The pins themselves are quite small and weak, however, so this must always be done with care.

Plugging in the battery lead and servo(s) completes all the connections required in the receiver circuit. The battery provides power for both the receiver and servo(s). A typical receiver draws about 10 milliamps (abbreviated mA) current when 'idling' (i.e. switched on,

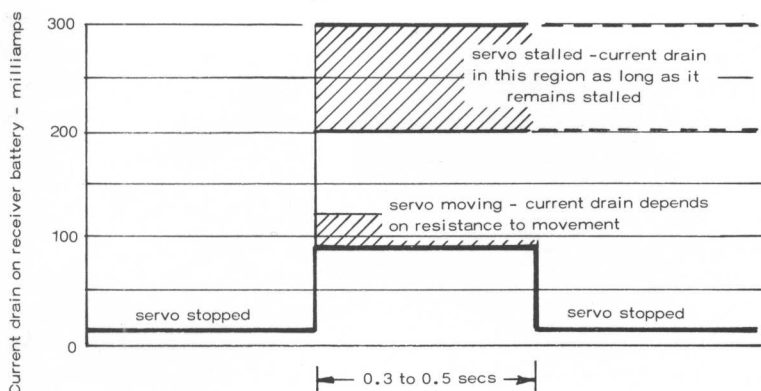


5.1 Typical current drain on receiver battery with one, two and three servos moving

but not responding to a transmitter signal). The current drawn will rise to about 70–100 milliamps when responding to a signal and driving a servo. (Remember, the receiver battery powers the servo(s) through the receiver circuit). If more than one servo is operated simultaneously, then obviously current drain will be higher still (*see* Fig. 5.1).

This higher current is drawn *only* when a servo is running to its signalled control position. Once it has reached this position it will switch off and draw no current, so current drain on the battery will fall to the idling current of the receiver. The exception to this is if the servo movement is stalled before it can reach its signalled position, e.g. by the linkage or control surface movement jamming up. Then the current drawn by the servo can rise to 200–300 milliamps and this drain will continue as long as the servo remains in a stalled condition. Under such conditions the receiver battery will quickly become discharged and the high current flowing through the servo amplifier circuit and the servo motor may even damage the servo.

With proper operation the *servo* draws current only when *moving* to a control position. If it has to push or pull against a heavy load it will draw more current when moving than if it were working against a light load. The difference on current drain may be as much as 25 milliamps or even more (*see* Fig. 5.2). Thus it obviously pays to keep



5.2 Servos draw much higher current when stalled before they have reached their full signalled movement

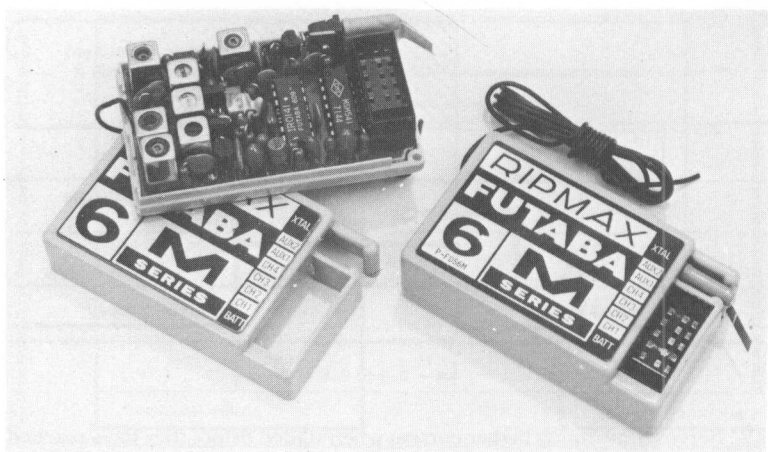
servo loads as light as possible, i.e. making sure control movements have minimum friction and, where advantageous, control surfaces are balanced (e.g. boat rudders).

The receiver battery is usually either a 4.8 volt Nicad type (rechargeable); or four 1.5 volt AA size dry batteries mounted in a battery box. Drycell batteries have one advantage *only*. It is cheaper, initially, to buy a set of dry batteries than a Nicad battery. But their useful life as a receiver battery is strictly limited.

Nicad batteries supplied with receivers in all-Nicad Combos may be of three different capacities—225 mAh, 500 mAh or 450 mAh. It is unlikely that the capacity will be marked on the pack, but the shape and size of the pack will be a clue.

225 mAh capacity battery packs comprise four button-type cells approx. 1 in. (25 mm) diameter and 0.4 in. (10 mm) thick, giving a cylindrical pack size (exclusive of any casing) of approximately 1 in. (25 mm) diameter by 1½ in. (38 mm) high. The 500 mAh capacity batteries are larger button-type cells giving a cylindrical pack size of 1⅜ in. (35 mm) diameter by 1⅝ in. (41 mm) high. 450mAh capacity battery packs comprise four cylindrical AA size cells giving a rectangular pack size (exclusive of any casing) of approximately 2 in. × 1 in. (50 × 25 mm).

Under average usage of controls, a 450 mAh or 500 mAh Nicad receiver battery will give a useful operating time of about 2½–3 hours in a 4-channel aircraft installation, operating four servos. On a glider,



Plug-in points for battery and servos are usually, but not always, marked on the receiver. The other 'plug-in' item associated with receivers is the interchangeable crystal.

with a 3-channel installation operating three servos—and where controls are used less than on a powered aircraft, operating time should be about $3\frac{1}{2}$ –4 hours. Rather longer times should be achieved on powerboats and yachts.

This is a feature which can only be checked out fully by practical experience with particular equipment. If you specifically need a longer operating time, then either you will need to use the servos less, or use a larger receiver battery. This often proves desirable, or even necessary, for 'duration' flying with gliders, but seldom in the case of powered aircraft, boat or car installations. The standard battery size provided with the original equipment is usually more than satisfactory in such cases, provided the batteries are fully recharged to start with.

Battery life with drycells is rather more difficult to predict. 'HP' type carbon-zinc batteries are normally used as they will give the best performance, with the current drain figures likely to be realized. But carbon-zinc batteries do not have a specific capacity rating, so their useful working life under operating conditions can only really be determined by experience. Non-rechargeable *alkaline* batteries of similar type, however, do have a definite capacity rating—and a generally superior performance under high current drains. They would be a preferred type for all-drycell working, except for the fact

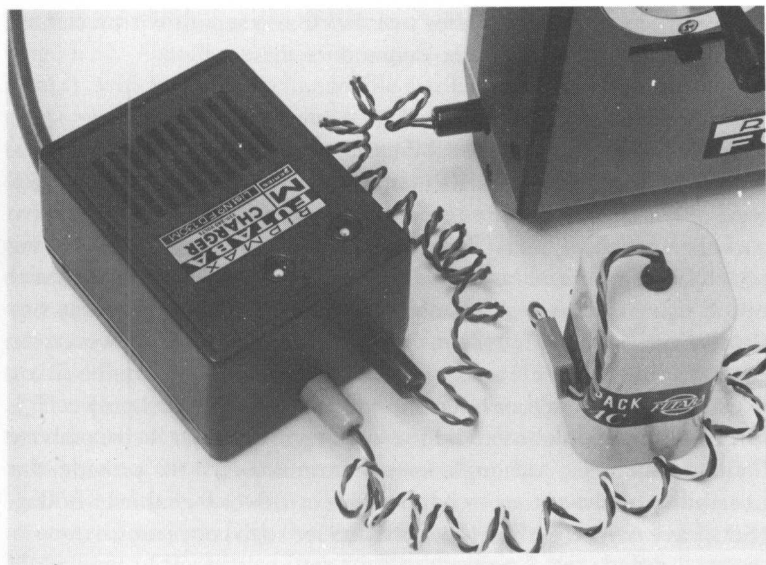
RECEIVERS

that they are about six times as expensive as carbon-zinc batteries for the same size. Also they are not rechargeable—so they are not realistically competitive with a Nicad battery. Two or three sets of disposable alkaline batteries would pay for an equivalent rechargeable Nicad battery.

For more information on batteries, battery performance and battery charging, see the separate chapter on 'Batteries'.

As a rough rule—although this is modified by the type of radio equipment used and how it is used—a drycell receiver battery (usually consisting of four AA cells) will provide a reasonably satisfactory working life for 2-ch or even 3-channel working, particularly if the servos employed are of low current drain type. Drycells also have the advantage that their condition (amount of discharge) can be checked. For 3-channel working a Nicad receiver battery would be better; and for 4-channels and above, a Nicad receiver battery is *essential* for reliable operation over a reasonable length of time.

Nicad batteries are also always preferred where the installation incorporates servos with a relatively high current drain, e.g. one or



Battery chargers, supplied or used with radio sets using Nicad batteries, can normally charge the transmitter and receiver batteries simultaneously; or independently, if required.

more servos which may have to work against a fairly heavy load, such as operating retractable undercarriages on aircraft. Again, however, much depends on the design of the particular servo used (*see* chapter on 'Servos'). Some servos designed for handling particularly heavy loads, e.g. sail winches, avoid this problem by being operated by a separate battery supply, thus relieving the receiver battery of excessive current drain when the servo is being operated.

More than one Receiver

Although a transmitter and receiver are referred to as a 'matched pair' the receiver supplied with a Combo is not an individually matched item. Any receiver of the same make and type will also match that particular transmitter. In other words, having bought a Combo, a second (or third, etc.) receiver can be bought to install in other models to be operated by the *same* transmitter. There is no need to buy a separate Tx-Rx Combo each time. The only requirement to match another (identical) receiver to a transmitter is the appropriate receiver crystal.

Almost all manufacturers offer spare receivers as a standard accessory item. Few, however, offer *transmitters* as a separate item as there should logically be little or no demand for these.

Spare Channels

It is not necessary to use all the channels provided by the receiver. Thus with a 6-channel Tx-Rx Combo, say, this will work equally well with only one, two, or three servos plugged in, leaving the other servo sockets unused. This is a point to bear in mind when considering purchase of an initial outfit. A 4-ch or 6-ch Combo may not cost very much more than a 3-ch Combo for a start, and you need only buy three servos to go with it if you only want three controls. However, the extra channel(s) are available with the 4-ch or 6-ch Combo if you want to add more servos later in a more ambitious model project. It is not usually possible to extend the working of a 2-ch or 3-ch Combo to further channels, although some manufacturers do provide this possibility of converting 4-ch transmitters to 5- or 6-channel working. (Sets have to be returned to the makers for such conversion).

Chapter Six

SERVOs

A SERVO, IN RADIO-CONTROL LANGUAGE, is an electro-mechanical device which converts the electronic signals received by the receiver into corresponding mechanical output movements. Basically, each channel provided by the Transmitter-Receiver Combo is capable of commanding one servo; and each servo offers the facility of one-powered or power-operated control. (Controls obviously have to be power-operated on models since there is nobody aboard to provide muscle-power.)

Physically a servo normally takes the form of a nominally rectangular 'box', rather smaller than the receiver, and fitted with external mounting lugs. It may be of *rotary* or *linear* type, describing the form of output movement provided. In a *rotary* servo the 'mechanical' output is a spindle carrying either a circular disc or specially shaped arm with a series of holes to which linkage can be attached (Fig. 6.1). Usually a servo is supplied with alternative disc and arm(s), which are interchangeable (*see* Chapter 9 to find out which type is used for different controls). In a *linear* servo the output is one (or more usually two) lug(s) sliding backwards and forwards providing a direct push-pull movement.

In both cases the internal components are similar, up to the final output movement. The source of power is a compact electric motor driving a multiple-reduction gear train to achieve a relatively slow output spindle rotation. This spindle carries the disc or arm in the case of a rotary servo; or has a small pinion gear engaging with a rack to drive the lug(s) in the case of a linear servo. (*See also* Fig. 6.2).

The electronic circuitry at the receiver end provides *proportional* movement of the output, relative to the 'command' initiated by movement of the transmitter stick controlling that particular channel. With the stick in the neutral position the servo movement remains in its centred position with the motor switched off—position 1, Fig. 6.3. Movement of the transmitter stick to position 2, say, half-full movement that way, introduces a signal to make the servo output move to its corresponding half-way position, 2, and remain there as long as the Tx stick is held in that position. Similarly, full movement of the Tx

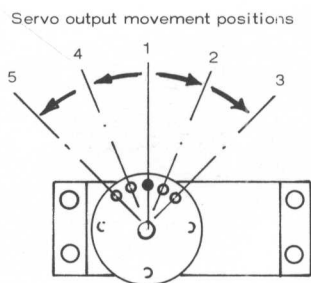
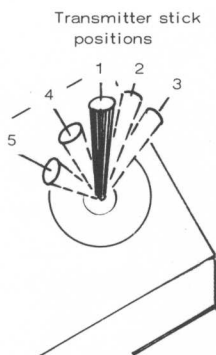


6.1 Servos come in two basic types, rotary or linear, but in various sizes. Included in this photo are a sail winch and a proportional speed controller for electric motors

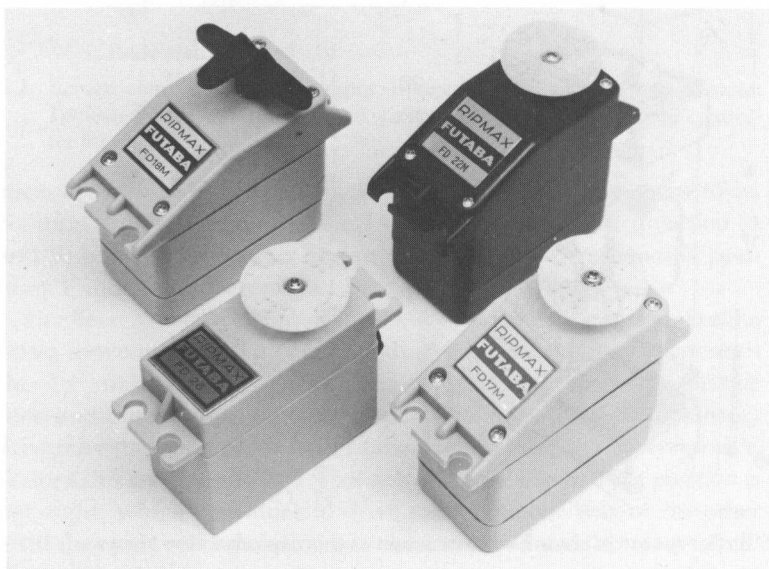
stick to position 3 will produce full movement of the servo to its position 3; or movement of the Tx stick in the opposite direction (4 and 5) will produce servo output movement to corresponding positions 4 and 5.

In effect, any movement of the Tx stick for that channel makes the servo movement seek a corresponding position and stay there until the Tx stick is again moved. The component responsible for this seek-and-hold positioning is a potentiometer (variable resistor) driven by the output movement (and enclosed within the servo case). It does this by generating a feedback or 'error' signal if the position is not right, which continues to drive the motor one way or the other until the exact corresponding position *is* reached and the 'error signal' disappears.

This 'adjustment' of positioning takes place extremely rapidly—virtually instantaneously in practical terms. It needs to be rapid for it is highly undesirable that any control position signalled—and particularly neutral—should be achieved positively, without the servo movement 'hunting' about for the right position before finally stopping there. In fact the degree of accuracy of positioning or *resolution* of a modern servo is usually very high (within 1 per cent).

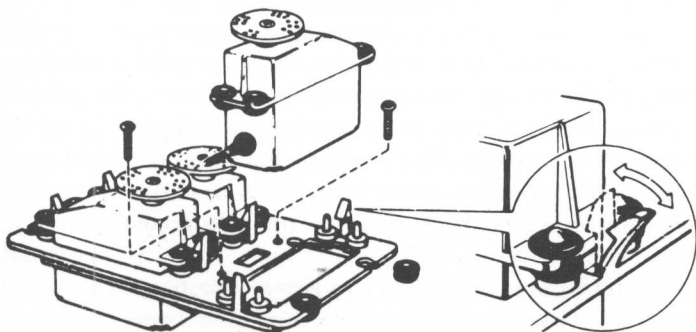
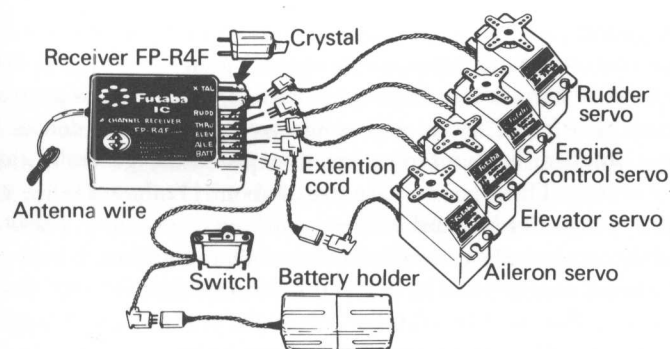


6.3 Illustrating how servo movement follows transmitter control stick movement.



Servos are fully enclosed in plastic cases fitted with mounting lugs. These are examples of rotary servos.

This is not usually a problem with normal installations, using good quality servos to start with, except to emphasize that servo life is not 'indefinite'. Servos may need servicing after an extended period of use. Also certain types of use are harder on servos than others. In



Batteries, servos and wiring harness with switch, all plug into the receiver (*top*). Typical servo mounting in a tray (*bottom*).

helicopters, for example, vibration levels are high and 'gear train wear' is likely to develop far more rapidly. Equally, on other types of models where excessive vibration is present, wear rates can be higher than normal.

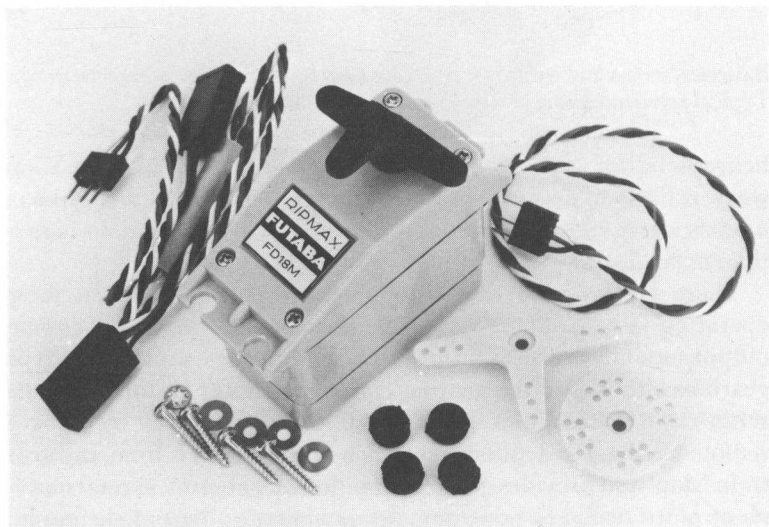
There are types of servos designed to take into account these operating factors. These may include ball races carrying the main output (spindles) instead of plain plastic bearings; and cassette-type gearboxes to isolate the gearing entirely from any distortion of the servo casing. Resolution can also be further improved by using a remote feedback potentiometer which both isolates it from any gear train 'slop' and provides greater potentiometer control, as total movement of an ordinary potentiometer is limited to that of the output (usually 90 degrees or less). A remotely located potentiometer, on the other hand, can have 270 degrees movement or the full range normally provided by the design of circular potentiometers.

RADIO CONTROL FOR MODELLERS

Sizes of Servos

A typical 'standard' servo size is about $1\frac{3}{4}$ in. $\times$ $1\frac{5}{8}$ in. $\times$ $\frac{3}{4}$ in. (44 $\times$ 41 $\times$ 19 mm) in case dimensions, excluding lugs. This is popularly classified as a 'mini' servo, and would weigh about $1\frac{3}{4}$ ounces (50 grams). Smaller, lighter servos are also produced, generally called 'micro' servos. These have a case size of about $1\frac{1}{2}$ in. $\times$ $1\frac{1}{2}$ in. $\times$ $\frac{3}{4}$ in. (38 $\times$ 38 $\times$ 19 mm) and a weight of about $1\frac{1}{4}$ ounces. These are obviously attractive for installation in smaller models although only representing a weight saving of about 2 ounces or less for a 'full house' aircraft installation. Even smaller servos are produced, weighing less than 1 ounce, although in more limited numbers.

Usually a 'micro' servo costs more than a 'mini' servo; and an even smaller servo, more again. Thus where space saving is not important, or critical, a standard 'mini' servo is a logical choice. Also the smaller the servo, the lower its power, so it is equally logical to use larger servos in larger models. On the other hand the availability of 'micro' and even smaller servos makes it possible to install a comprehensive radio control system in models too small to accommodate 'mini' servos.



Typical servo shown with alternative output arms or disc, grommets and mounting screws. Item on left is a T-junction lead for connecting two servos in parallel to one receiver outlet.

SERVOS

In the case of a *rotary* servo the output movement is normally of the order of 45 degrees either side of neutral position. With a typical disc diameter (or arm length) of 7/8 in. to 1 in. (22 to 25 mm) this will provide actual push-pull movements ranging from about 5/8 in. to 3/8 in. (16 to 9 mm), depending on the hole position to which the pushrod is attached (Fig. 6.4).

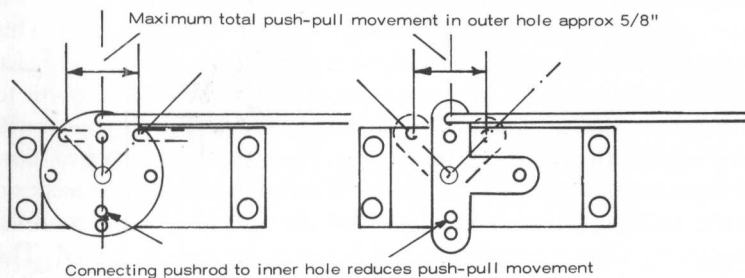
With a *linear* servo the movement is fixed by the design. It does not provide for alternative push-pull movements. Movement available is usually about 5/16 in. (8 mm) either side of neutral, i.e. a total push-pull movement of 5/8 in. (16 mm).

Rotary servos are the more prolific, and the type most commonly used for operating controls on all types of models. Linear servos may be used where space-saving is important. In particular, they can be placed flat within the centre section of a wing for operating ailerons. They may also be preferred for a throttle control since they have a true linear movement. (With a rotary servo output push-pull movement 'slows up' as the output disc approaches the end of its rotation).

Retract Servos

A *retract* servo is designed specially for operating retractable undercarriages on aircraft models. It is generally a modified form of standard rotary servo with higher reduction gearing giving an increased pull at the expense of slower operating time. The output movement is also usually greater, e.g. up to 170 degrees rotation instead of the usual 90 degrees, a full movement taking 2-3 seconds.

The 'command' circuitry of a retract servo also usually works in a different way. The servo has no 'neutral' position but merely moves from one extreme position to another, triggered by a single command



6.4 Maximum movement available from servos is limited

signal. If operated by a separate non-proportional Tx channel, the control on the transmitter takes the form of a switch or a pressbutton. Operating the transmitter switch one way (or pressing the button) makes the servo run to its full position one way, stop and switch off. Moving the switch the other way (or pressing the button again) makes the servo run to its other extreme position, stop and switch off.

If the retract servo is connected to a *proportional* channel, then exactly the same type of response will be triggered by movement on the corresponding Tx stick in *one* direction only. In other words, first movement of the stick one way will start the servo which will run to its full position and stop. A second movement in the *same* direction will reverse the servo. Movement of the stick in the other direction will not produce any response from the retract servo.

Coupling a retract servo to a *proportional* channel really 'wastes' half of that control channel. Thus transmitters providing more than 4 channels usually include one *non-proportional* channel specifically for operating a retract servo. This type of response from a retract servo also makes it suitable for operation by triggering a switch movement from a servo already used for *another* control, i.e. making it possible to operate retractable undercarriages with a radio which does *not* have an additional channel available for this service (see Chapter 10 for more details of 'coupled' controls).

Equally, since the true retract servo does not respond *proportionally*, and does not have movement either side of a neutral position, it is not a more powerful substitute for a normal servo for operating conventional controls.

Performance Parameters

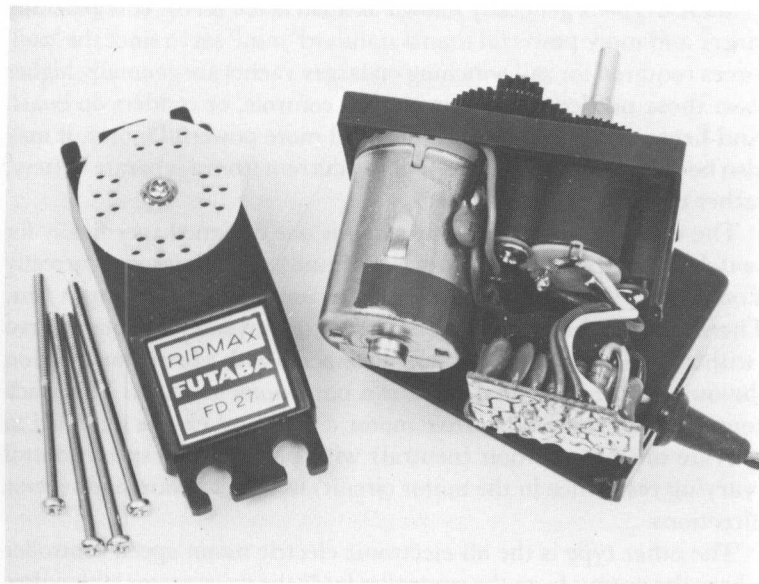
The typical output *movements* of servos have already been described. The time to complete movement from its neutral position (or starting position in the case of retract servos) is known as the *transit time*. This is largely determined by the output gearing which is selected to give an optimum response—not too rapid as to produce jerky response to control movements and not too slow, otherwise control response will be sluggish. In practice, a transit time of less than $\frac{1}{4}$ second is too fast. A transit time greater than about $\frac{1}{2}$ second is too slow, except on large models. Most servos intended for operating main controls, therefore, have a transit time of between $\frac{1}{3}$ and $\frac{1}{2}$ second. The exception is retract servos which may have a transit time of up to 2 or 3 seconds.

SERVOS

The output 'power' of a servo is normally expressed as its 'push' or 'pull' force exerted on a push rod in the outer hole of the output disc or arm. In actual fact it is a *torque* or output spindle 'turning force' which is produced. So the true output force available depends on which hole on the disc or arm the pushrod is connected to. In the case of a linear servo, of course, there is no possible variation in effort; only the actual push-pull output of the sliding lug.

The limiting performance of a servo is then represented by its *stall force*, or level of load which will prevent it moving at all. Typically this may be 4-5 lb. in the case of a 'micro' servo; 7-9 lb. in the case of a 'mini' servo, and up to 15 lb. or more in the case of a retract servo. Few manufacturers quote specific figures and comparative data are usually only obtainable by actual tests.

Accuracy of response of a servo to proportional positioning is called *resolution*. This is not a critical factor as far as control positioning is concerned, except on more elaborate systems. What is far more important is accuracy of self-centering. Ideally, when the transmitter



Heart of a servo is a sub-miniature electric motor driving the output spindle through reduction gearing. A potentiometer mounted on this spindle provides 'feedback' signals to the electronic circuit.

control stick is released and centres, the servo should respond exactly, without 'hunting' about neutral before settling down. An inferior servo may not only 'hunt' appreciably but also finally settle in slightly different neutral positions each time.

Special Servos

Certain control operations may call for movements not readily obtainable from the output movements of standard servos. Adjusting the sail setting on model yachts is an outstanding example. This may call for sheet hauling travels of up to 12 in. (305 mm) or more. This may be realizable with 'lever' movements, but a continuous rotary movement to provide true 'winching' action is obviously a better solution.

This calls for a modified form of rotary servo fitted with a drum instead of an output disc or arm and with a maximum movement of ten or more complete revolutions. In other respects it responds just like a standard proportional servo, but is designed and used purely for winching movements.

Such a type is generally known as a *sail winch* servo. It is generally larger and more powerful than a standard 'mini' servo since the 'pull' forces required for sail winching on larger yachts are generally higher than those needed to operate aircraft controls, or rudders on boats. And because this calls for a larger and more powerful motor, it may also be designed to draw its operating current from a separate battery, rather than the receiver battery.

The other main special-type servo is one designed specifically for switching- and speed-control of electric motors. This is more correctly a *controller* rather than a servo as it does not provide any output *force*. There are two basic types. The first is a conventional rotary servo (with a larger than usual output movement) with a brush mounted on the output arm and rotating over a potentiometer track. This track connects into the model drive motor circuit and can be designed to provide an 'off' position (neutral) with proportional speed control (varying resistance in the motor circuit) in both forward and reverse directions.

The other type is the all-electronic electric motor speed controller where the output from the controller feeds the drive motor with pulses of direct current. The pulse rate can be infinitely varied from 'all off' (or 0:100 mark: space ratio in technical language) to 'all on' (100:0 mark: space ratio) for either direction of running of the motor.

SERVOS

The all-electronic type can provide far finer speed control and also has the advantage that it does not waste battery power at intermediate speed settings. (A potentiometer type speed control reduces speed by 'losing' current in the resistance track, which loss shows up as heat). It is, however, considerably more expensive than the potentiometer type.

Both types of speed controllers have a limited power output rating, e.g. so many amps maximum current drain at a specified voltage, normally expressed as a wattage rating. (Watts equals volts *times* amps). They should always be used with a fuse in the circuit to ensure that the maximum current rating cannot be exceeded.

Chapter Seven

CHOOSING AN OUTFIT

CHOOSING THE BEST OUTFIT for your own use is not easy, particularly as one of the most important considerations is usually cost. But initial cost alone is *not* the most important factor in the long run. For example, if you anticipate using a radio-controlled model (or models) fairly frequently, an all-drycell outfit which offers a substantial saving in initial cost over an equivalent all-Nicad battery will have cost you *more* after you have used more than about ten sets of dry batteries. (And for aircraft, to be safe, you really need to change receiver *drycell* batteries after every flight).

A point to bear in mind here is that with an all-drycell Combo the transmitter battery is usually eight cells (12 volts) and the receiver battery four cells (6 volts). Nicad batteries are available in the same physical size as AA cells, so would actually fit the same battery boxes. However, Nicad cells develop only 1.2 volts per cell, so changing the transmitter battery to Nicads would only give 9.6 volts; and changing the receiver battery would only give 4.8 volts.

With some Combos this will work—making it easy to convert from dry batteries to (rechargeable) Nicads, simply by using Nicad cells in the original battery boxes. This will generally be cheaper than buying equivalent Nicad battery *packs*. The only disadvantage is that the Nicad cells are relatively loosely mounted in the battery boxes, so to ensure that they are not displaced they should be taped in place securely; still not quite as good as a Nicad battery *pack* which has welded intercell connections—but less expensive. Trying to make a more permanent ‘pack’ by soldering separate Nicad cells to battery box connections will not work. Nicad cell connections are virtually ‘unsolderable’ (and cells could be damaged by excessive heat in attempting to do so).

With other drycell Combos a direct substitution of AA size Nicads for drycells will *not* work. The resulting battery voltages are too low for the design of the circuit. It would need additional Nicad cells in each battery to make up the required voltage packs (e.g. ten Nicad cells to give 12 volts and five Nicad cells to give 6 volts.).

Summarizing, then, if you *do* decide to buy an all-drycell Combo to



Example of a low-cost 2-channel outfit which can be operated on dry batteries (receiver battery box shown); or on Nicad batteries.

keep initial cost down to a minimum, and plan to convert to Nicad batteries later—buy a drycell Combo with *is* specified as suitable for drycell *or* Nicad working, using the same physical sizes of batteries.

Then there is no real economy in buying a 2-channel outfit for a first model when you anticipate progressing to further models which may need 3- or 4-channels. This is particularly true in the case of aircraft. A 2-channel outfit could get you started with a radio-controlled glider, but you will almost certainly want to progress from there to a 3-channel glider, or an R/C trainer, and then on to a 'full house' system for powered aircraft.

Now the cost of a 4-channel Combo with *two* servos for a start will not be very much more than a 2-channel Combo with two servos of the same make and performance. For the next model which requires 3 channels or 4 channels you then only have to buy one servo (or two servos)—not a complete new 3-channel (or 4-channel) outfit.

Recommended outfits therefore (*see also* Chapter 3) are:

Gliders

An all-drycell 2-channel (or preferably 3-channel) outfit if you *must* economize for a start, as these are to be found available at very low prices. But be sure to buy a reputable brand, and even then only regard this as a 'starter' outfit.

Best buy, a 3-channel all-Nicad Combo (or preferably a 4-channel all-Nicad Combo, with just two or three servos as needed).

Powered Aircraft

Regard an all-Nicad Combo as *essential* in this case. Full control coverage demands the use of a 4-channel outfit (even if you only need 3-channel for a start with an R/C trainer). So buy a 4-channel Combo and the number of servos you actually need for a start; or a 6-channel Combo if you can afford it. This will give you all the control coverage you are likely to need for future models.

Check on different leading makes. Some 4-channel transmitters are convertible to 5- or 6-channels if you need more coverage later, and may even be supplied with a 6-channel receiver in the first place.

High-Speed Power Boats

Again, regard an all-Nicad Combo as *essential*. A 2-channel outfit will give you all the functional control coverage you are normally likely to need, but for racing consider a 3-channel outfit as offering the possibility of adding transom flaps as a worthwhile additional control.

Electric Powered Boats

A 2-channel outfit is all you really need, unless you are interested in scale models and would like to introduce additional working features. Because electric powered boats operate at relatively low speeds, radio failure through flat batteries is not likely to have drastic consequences. Also the amount of time servos are actually operated is much lower than with aircraft—so an all-drycell 2-channel outfit can prove quite satisfactory.

Fast-Electric Boats

A 2-channel all-Nicad outfit is the logical choice here as loss of control could be expensive in terms of damage to receiver, servo(s), drive motor and very expensive main (propulsion) batteries. Motor control can be reduced to on-off switching, simplifying second servo requirements.

Yachts

You will need to use rudder control more on yachts than electric boats, and with sail winching also, battery current demand will be fairly high. A 2-channel all-Nicad outfit is the logical choice; or a 3-channel all-Nicad outfit if you intend to take up class racing seriously. This will give you the opportunity to add a separate jib-trimming control.

Cars

A 2-channel Combo is all you really need, giving one control for steering and one control for motor speed. With this you will need two servos—one for steering and one (usually) for motor speed control. Many electric R/C cars already incorporate a potentiometer-type speed controller for the motor, the second servo connecting directly to this. With some others—and cars built from scratch—you will need one servo (for steering) and one speed controller (for motor control). With I/C-engined cars you need two servos, the second servo linked directly to the engine throttle.

Brand Names—and Prices

Originally the United States led the world in the development and manufacture of radio-control sets, subsequently being overtaken by Japan. With the appearance of proportional radio Japan became by far the largest manufacturer with outfits sold both under their own brand names and, more recently, virtually identical sets sold under other names in the United States, Great Britain and Continental Europe. Few 'home' manufacturers in USA, Britain and Continental Europe have been able to remain competitive in performance and price with leading Japanese equipment.

By 1978 Japanese production had reached unprecedented levels (something like 300,000 sets produced annually), particularly in the 2- and 3-channel outfits, anticipating a huge boom in demand both in Japan and world-wide for lower cost equipment for simpler models,



Action can be fast and furious with an I/C engined R/C car. Many of these models have special tyres and suspension for running on rough ground.

particularly R/C cars. Similar productions also appeared in other Far East countries at even lower prices because of the lower labour costs in such countries as Taiwan, Korea and Hong Kong.

The anticipated boom did not materialize, with the result that many Far East manufacturers were faced with large unsold stocks. These were virtually off-loaded on to any country that would take them, at drastically cut prices. Prices were also affected by the fact that at this time the Japanese yen became a weak currency with export prices correspondingly cheaper.

A proportion of cut-price exports were by reputable manufacturers and represented genuine bargain-price radio. The remainder ranged from reasonable to dubious, or even downright unacceptable in performance. Price alone was no guide because disposal of surplus stocks simply led to a cut-price war with 'quality' outfits competing with 'rubbish' at similar levels.

Britain, unfortunately, became a prime target for offloading some of the more unsatisfactory equipment because of the relatively lax regulations governing the performance requirements of model radio

controls. In the USA, and Germany in particular, government regulations are extremely strict as regards transmitter performance. Even some first-class outfits, accepted and recognized as such in other countries, do not meet German regulations and would not be an acceptable import without modification to conform. Britain, on the other hand, was so lax that it even permitted the sale of Citizen Band radios, which were illegal to operate in this country until the relaxation of this restriction in late 1981 (*see also* Appendix IV).

Without 'inside knowledge', choosing a set purely by advertisement appeal can therefore lead to a disappointing purchase. And really the only valid 'inside knowledge' is experience of how a particular manufacturer's radio performs over a long period of use, in other words, brand names that have stood the test of time—and competition from other sources. Even this is no complete answer as some of the new, hitherto unknown, brand sets may prove as good as any—or very much worse!

Logically the source of such 'inside knowledge' is the *model* shop that sells *radio control*. A shop run by someone with practical experience in, and an enthusiasm for, radio control who will already have used his own judgement in selecting his stock of radio control outfits; the model-shopowner, in fact, who is wanting a satisfied customer who will come back for more.

Another important point is servicing. Things can go wrong with even the best of radios, and equipment can be damaged in a crash. This can only be dealt with by experts with a good knowledge of the equipment involved and suitable stocks of spares. Before buying imported sets, therefore, it is important to confirm that it is backed by a reputable service and spares service *in this country*. This is invariably the case with the top branded Japanese radio—(Futaba, Sanyo, etc.); but not necessarily the case with recent low-price importations.

AM or FM ... or even UHF?

An AM set (*see* Chapter 1) is cheaper than an FM set. Under average conditions the better interference-rejection of an FM set is not usually significant, so the extra cost will not automatically provide superior performance. If local interference is a problem (*see below* 'Finding Out') then an FM set may be a better proposition. Or you might give serious consideration to a much more expensive UHF set to get round this particular problem.

RADIO CONTROL FOR MODELLERS

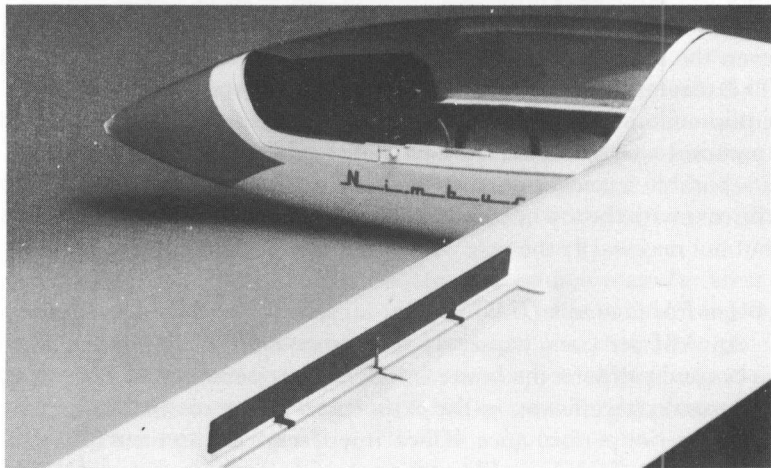
Again there can be a marked difference in brand performance. An FM set should be better than a AM set of the same brand. But an FM set of inferior brand may be worse than an AM set of a superior brand in the matter of interference—rejection and reliability.

Finding Out

A lot of the answers to questions raised regarding the selection of a suitable make and type of set can be found by joining a local model club that operates radio-controlled models of the type you are interested in—aircraft, boats or cars. Members will know from experience which sets perform well, if there are any problems with local interference—and will probably hold strong views on the reliability of certain sets! Buying the same set that other local modellers are using successfully is also helpful in sorting out problems which may arise. They have probably had similar troubles—and know the answers to them.

Finally...

Contrary to popular belief there is not much difference between the basic performance of similar sets of reputable make. The brand leaders produce fully developed ranges of Combos and servos which have been in production for a period of years and which are fully



Large R/C sailplanes have such a flat gliding angle that wing spoilers (air-brakes) can be a highly desirable extra control to make landing easier.

CHOOSING AN OUTFIT

capable of doing the job they are designed for. Differences that do occur are mainly a matter of *reliability* of operation and servo life.

Two other points worth bearing in mind are:—

1. With most electronic circuits, if there is a manufacturing fault present, this will usually show up in the initial period of use. Otherwise if the design is sound the circuit should continue to give long trouble-free operation, unless abused. All new sets are normally covered by a year's guarantee against faulty workmanship or components.
2. Initial production of any entirely new set, even a well known brand name, is to some extent 'suspect' until its performance has been proven by use. The unexpected can often show up when a set which has been developed and tested by a team of experts is put into use by hundreds or thousands of other individuals operating in different places and under different conditions. (As is only too well known, the same sort of thing happens with any new car put into production—but radio reliability is usually far better than new car reliability!).

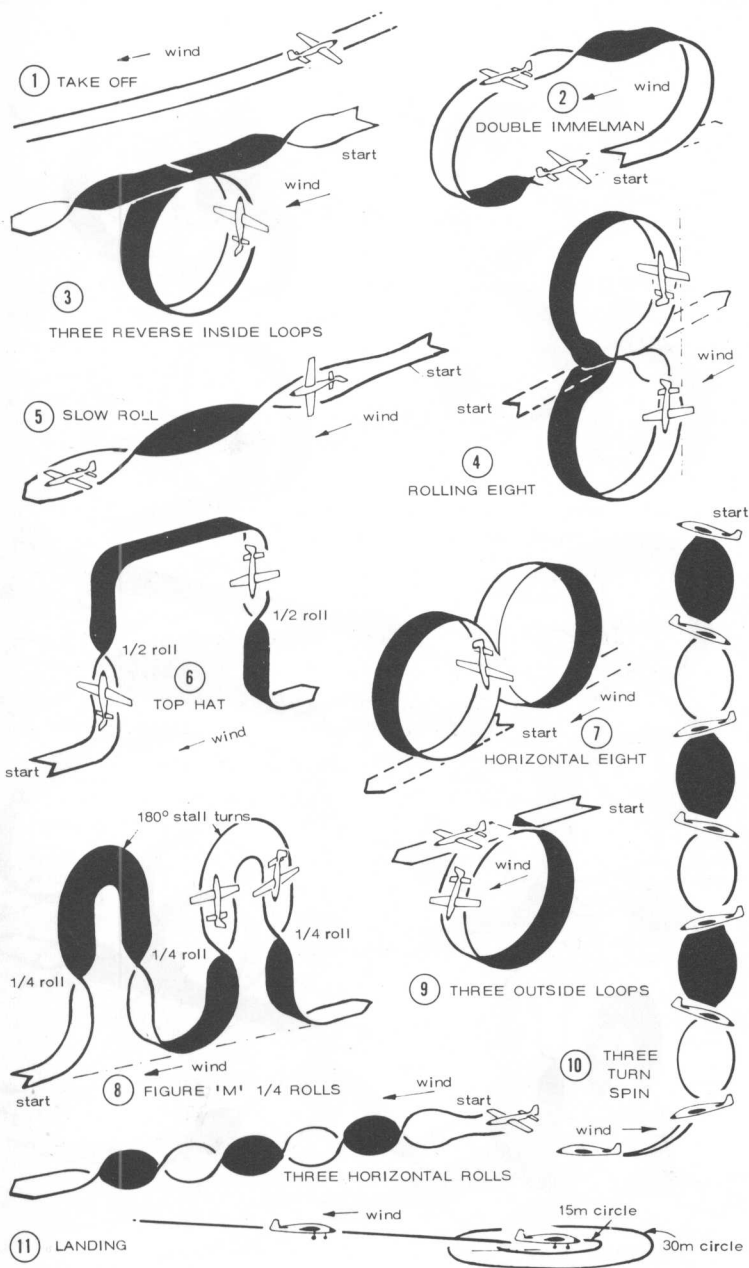
Chapter Eight

MORE SOPHISTICATED OUTFITS

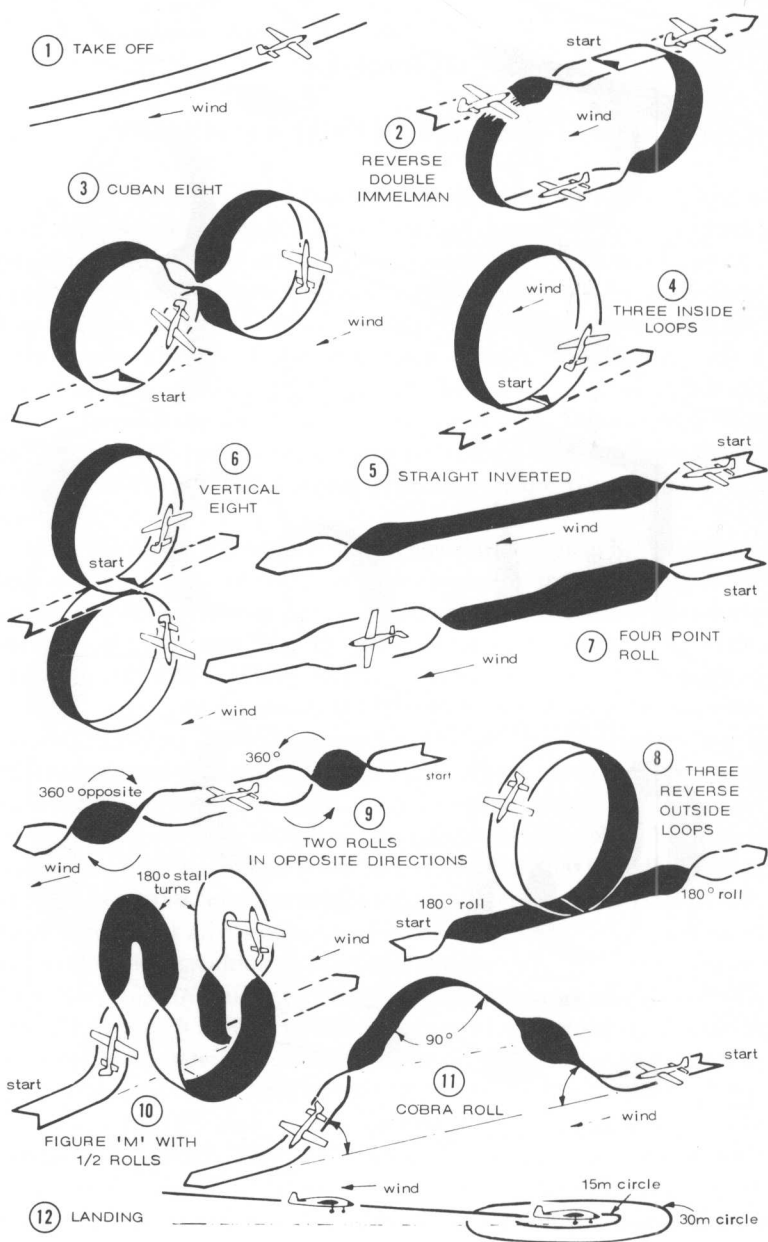
THE TWIN-STICK 6-CHANNEL TRANSMITTER controlling elevators and ailerons on one stick, and rudder and throttle on the other stick, provides all the basic control requirements for a fully aerobatic aircraft—with a fifth (proportional) channel available for controlling flaps; and a sixth (non-proportional) channel for working a retractable undercarriage. The manoeuvres possible to perform with a modern, fully aerobatic R/C aircraft (known as a 'pattern' model) extend beyond the capabilities of full size aircraft. What is more they are performed regularly at top-class competition level, reflecting great skill (and a lot of flying practice) on the part of the pilots involved.

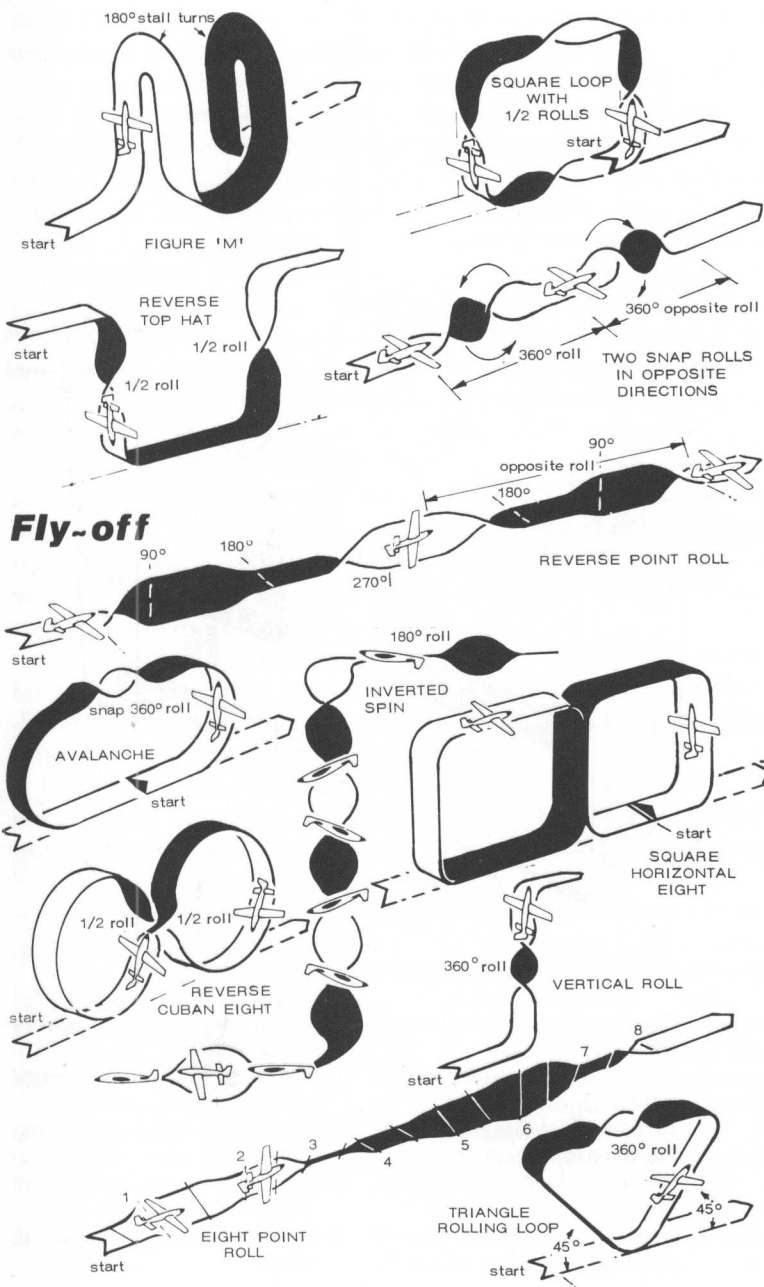
Figs. 8.1 and 8.2 illustrate the full standard range of R/C aerobatic manoeuvres, many of which call for absolutely precise timing in the use of two or more controls simultaneously. And until comparatively recently all this has been done by using perfectly standard radio control equipment, relying mainly on practice (with a suitable model design) to achieve the ability to reproduce each standard manoeuvre as accurately as possible. There have been a few exceptions, e.g. a rearrangement of transmitter control positions, for example, putting the throttle control in the form of a twist-grip on the top of one stick so that this one stick then controls three separate controls. This gained some favour at the time, but was not widely accepted. Re-allocation of control positions has also been tried but in terms of practical advantage only seems advantageous with trim controls. With the left hand stick controlling rudder and throttle, and the right hand stick controlling elevators and ailerons, location of *throttle* trim against the (left side of) *right* stick and the *elevator* trim control against the (right side of) *left* stick can provide smoother manipulation of these trim controls using the right thumb and left thumb, respectively.

A more useful feature is to be able to vary the *movement* response of certain controls, particularly ailerons. For normal turns, only moderate aileron movements are required. For snap rolls, quite large movements are needed. Whilst this can be controlled by normal stick movement, if full stick movement results in large aileron movement,

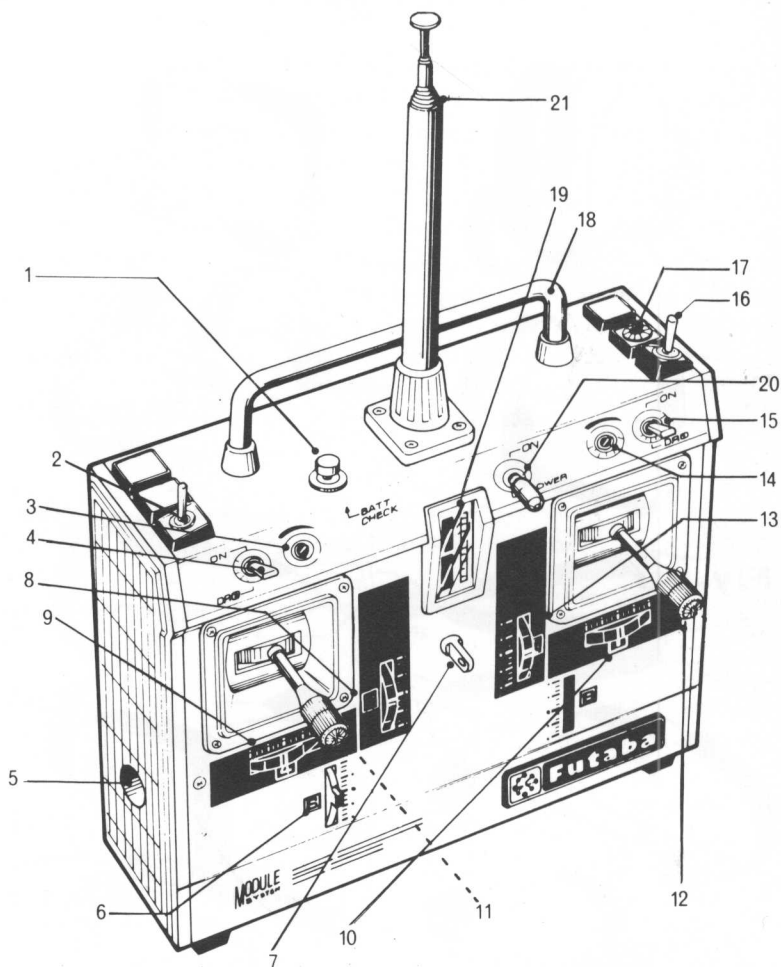


8.1 a & b and 8.2 The standard range of manoeuvres for R/C aerobatic aircraft.





Fly-off



8.3 Advanced 6-channel transmitter (Ripmax-Futaba 'J' series).

Key:

- | | |
|---|--|
| 1. Battery check (press to read battery voltage). | check out system with Tx switched off. |
| 2. Undercart retract/extend switch. | 6. Flap control with graduated movement |
| 3. Elevator dual rate (movement adjust) trimmer. | 7. Neckstrap hook (neckstrap suspension recommended to facilitate easy operation of all the various controls). |
| 4. Elevator dual rate selector switch. | 8. Elevator trim (adjacent to LH stick). |
| 5. Charger point—also plug-in point for working servos to | |

the smaller range of stick movement needed for turns makes control of turns somewhat critical to set up with consistent accuracy.

A number of the more advanced types of transmitters, developed with precision and contest flying requirements in mind, provide *dual-rate* switching facility on one or more channels. Thus with dual-rate switching available on, say, the aileron channel, one position of this switch will give maximum aileron travel for rolls, whilst the other position of the switch will give reduced movement for turns from the same actual (transmitter) control stick movement. It is useful, also, to have dual-rate switching available on the elevator channel.

The disadvantage of dual-rate switching is that in the hands of the not-so-expert pilot the wrong travel (i.e. wrong position of the switch) might be selected accidentally without the pilot becoming aware of it, which could lead to drastic consequences at times.

A feature with more general value, also found on many more advanced transmitters, is switches for reversing the direction of rotation of servos. This means that servos can be installed and coupled up regardless of their direction of response and the servo-reverse switch(es) on the transmitter adjusted, as necessary, to get the servos responding in the correct sense.

More sophisticated transmitters may also provide adjustable travel for individual servos, and/or adjustable servo neutral positions. Again these are pre-set controls which, once correctly adjusted during initial set-up are left alone.

Even more useful from the advanced pilot's point of view is the development of control 'mixing' systems which allow a predetermined amount of a particular control movement to be produced

-
- | | |
|--|--|
| 9. Rudder trim under rudder stick. | 16. Elevator/flap 'mixing' switch. |
| 10. Aileron trim (under RH stick). | 17. Elevator/flap mixing trimmer. |
| 11. Rudder/throttle control stick, adjustable length. | 18. Carrying handle. |
| 12. Aileron/elevator control stick, adjustable length. | 19. Level meter reads battery voltage (with battery check switch pushed); or continuously displays RF output with power switch on. |
| 13. Throttle trim (adjacent to RH stick). | 20. Power switch with safe on/off locking. |
| 14. Aileron dual rate (travel adjust) trimmer. | 21. Telescopic aerial rotates to lock in position when extended. |
| 15. Aileron dual rate selector switch. | |

RADIO CONTROL FOR MODELLERS

automatically when another control is operated. For example, rolls require the use of ailerons, elevator *and* rudder to perform this manoeuvre properly. If the facility is available to 'mix' rudder with the stick movement controlling ailerons and elevators, then this manoeuvre can be commanded on *one* stick, not two. There is the further advantage that once the degree of rudder 'mixing' is preset correctly, it will be repeated *exactly* every time this manoeuvre is called for. With standard controls the amount of rudder 'mixed in' depends



Sanwa outfit shown here is another example of a modern system with 'expert' or 'professional' standard facilities.

each time on separate manipulation of the rudder stick, with reliance on the pilot himself not to make a mistake.

'Mixing' of controls can be achieved mechanically or electronically. Mechanical mixers are the simplest to understand and set up. Their disadvantage is that they are normally *coupled* controls. For example, simple mechanical mixing of rudder with elevator always produces a predetermined amount of rudder movement whenever elevator control is used. This can be desirable at times, but undesirable at others.

Provided an additional control channel is available, an electronic mixer has the advantage that it can be switched in or out. In other words, it can be left 'off' for normal manoeuvres, and switched 'on' to perform specific manoeuvres. Carried to its logical conclusion an electronic mixer can, in fact, provide the equivalent to an automatic pilot for performing a specific manoeuvre. Press a button, say, and the aircraft will perform a snap roll. How perfect the manoeuvre is will then depend on the accuracy with which the 'mixed' controls concerned have been pre-set.

The most advanced system of this type so far to appear is the Futaba J series 8-channel transmitter, the functions provided by which are annotated in Fig. 8.4. This is a conventional transmitter as far as the twin stick arrangement is concerned, except for the allocation of trim positions in the manner described previously. Further directly signalled functions (controls) available are then:

Channel 5 – Undercarriage retract gear, switch operated.

Channel 6 – Proportional control of flaps (ratchet braked) plus separate trim control.

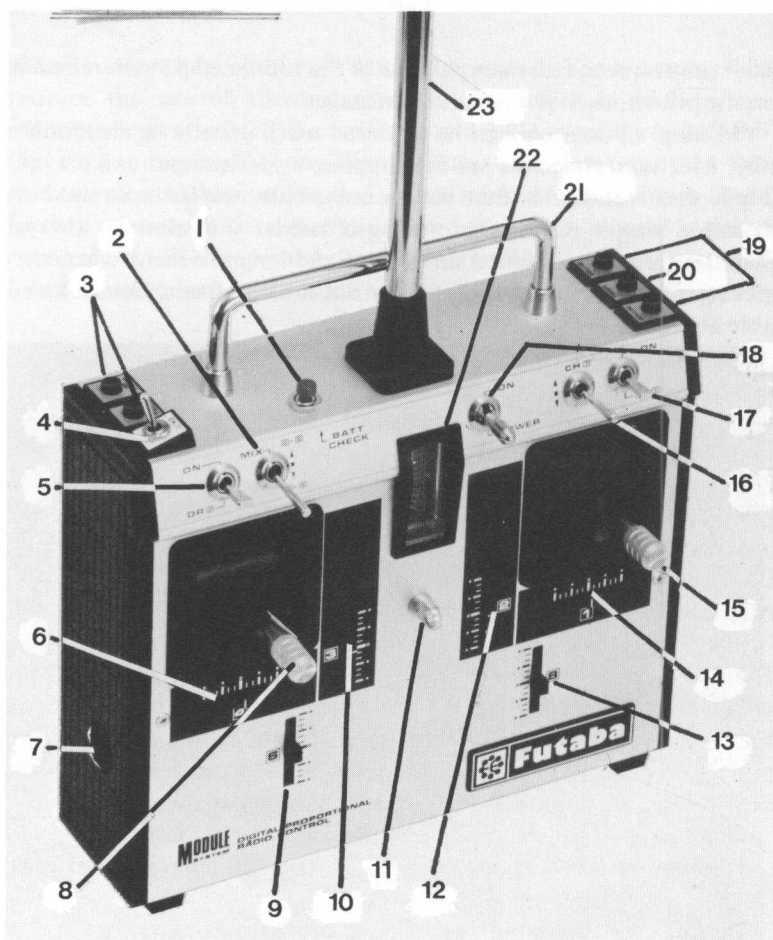
Channel 7 – Available for spoiler or airbrakes, etc.

Channel 8 – Available for any further control required.

The four main functional controls operated by stick movements are allocated as follows:

Channel 1 – ailerons	}	on right-hand stick
Channel 2 – elevator		
Channel 3 – rudder	}	on left-hand stick
Channel 4 – throttle		

Additional switches and pressbuttons are then provided for 'mixing' controls. Switch 2 provides simultaneous elevator and flap movement (or spoiler and flap movement). In other words it 'mixes' pre-set movements of the two controls normally operated by the right-hand stick and separate Channel 6 control.



8.4 Advanced 8-channel transmitter (Futaba 'J' series).

Key:

1. Battery check (press to read).
2. Elevator/flap or spoiler/flap mixing selector couples selected pairs of controls in pre-adjustable proportions.
3. Snap roll buttons—give separately pre-adjustable aileron, elevator and rudder movement for perfect snap rolls on one command. Use A for right rolls, B for left rolls,
4. Undercart retract/lower switch.
5. Elevator 'dual' switch selecting alternative elevator throw (pre-adjustable).
6. Rudder trim under rudder stick.

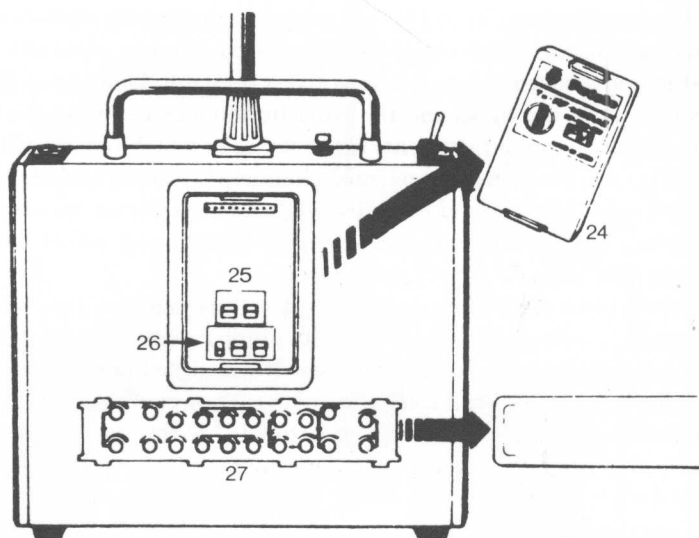
set up to match the aircraft. 'Pulse' for hesitation rolls—or you can also set up for spins instead of rolls.

The pressbuttons (19 on Fig. 8.4) provide an even more sophisticated 'mixing' control. When one of these is pressed, ailerons, elevators and rudder move to pre-set positions to give a snap roll. One button gives a snap roll to the right, and the other button a snap roll to the left, these separate pre-adjustments being set up to match the aircraft. In other words, the pressbuttons 'mix' channels 1, 2 and 3 and in preset proportions. The pressbutton between the two is a further 'automatic' service. Pressing this changes the engine throttle to a preset setting during snap rolls (or other manoeuvres).

Preset 'mixed' ailerons, elevator and rudder can also give hesitation rolls (i.e. by pulsing the command button); or can be adjusted for spins instead of rolls. In the latter case the throttle button can again be used rather than the throttle control to cut power at the commencement of the spin—automatically reverting to full throttle for recovery when the button is released. (The button holding on 'spin' would be released first.)

Controls for adjusting and setting up the movements to be mixed by the appropriate command switch or button are located on the back of the transmitter—Fig. 8.5 adjustment can, of course, only be done by trial and error and can be very time-consuming. The 'automatic pilot' facility of selectable, mixed controls is only fully reliable *after* it has been set up properly.

-
- | | |
|---|---|
| <p>7. Charger point—also plug-in point for direct connection to receiver to check operation of servos with Tx switched off.</p> <p>8. Rudder/throttle control stick, adjustable length.</p> <p>9. Flap control with graduated ratchet movement.</p> <p>10. Elevator trim, operated by other hand for smooth control.</p> <p>11. Neckstrap hook.</p> <p>12. Throttle trim, operated by other hand for smooth control.</p> <p>13. Channel 8 control.</p> <p>14. Aileron trim under aileron stick.</p> <p>15. Aileron/Elevator control stick, adjustable length.</p> <p>16. 3-position Channel 7 switch (e.g. for spoiler, airbrake, etc).</p> | <p>17. Aileron dual switch for selecting alternative throw (pre-adjustable) aileron.</p> <p>18. Safe-locking on/off power switch.</p> <p>19. Roll buttons—give pre-adjustable rate of roll via ailerons to both left and right.</p> <p>20. Throttle button—to select and stop the throttle at a pre-determined position during snap rolls, etc.</p> <p>21. Carrying handle.</p> <p>22. Level meter reads voltage (with battery check switch depressed); or, continuously displays RF output.</p> <p>23. Telescopic aerial, rotates to lock-in position when extended.</p> |
|---|---|



8.5 Preset controls on back of the 8-channel transmitter shown in Fig. 8.4.

Key:

- | | |
|--|---|
| <p>24. Removable FM transmitter module. Removal exposes servo reversing switches and high/low throttle tick-over switch, and also enables Tx crystals to be changed. Second panel detaches to allow access to pre-adjustable trimmers. FM modules are available for 27MHz, 35MHz, 40MHz,* 53MHz* and 72MHz.*
* Not for use in the U.K.</p> <p>25. Switches for reversing direction of rotation of aileron, elevator, throttle and rudder servos.</p> <p>26. High/low tick-over switch.</p> | <p>27. Trimmers for adjusting travel of individual servos for dual rate; adjusting amount of mixing; ATV-function for independent adjustment of servo travel either side of centre (applicable to rudder, elevators and ailerons); and other various presets for use by the modeller himself. Matching FM Receiver is of module type with interchangeable crystals. To change to a different frequency band, simply replace with appropriate module. Size 49 × 42 × 24mm. Weight 52g.</p> |
|--|---|

Additional adjustments provided with this particular transmitter include:

1. Switches for reversing direction of servo rotation.
2. Throttle change-over from high to any lower, or tick-over, setting (initiated by the throttle pushbutton).

MORE SOPHISTICATED OUTFITS

3. Trimmers for adjusting travel of individual servos for dual-rate operation.
4. Independent adjustment of servo travel either side of neutral.

Another feature is the *frequency module*. With the transmitter designed for world-wide use, only the radio frequency side of the circuit is affected by the transmission frequency to be used. Interchangeable modules are thus made available, both for AM and FM working, on 27MHz, 35MHz, 40MHz, 53MHz and 72MHz, covering world requirements (*see* Appendix II). Any one module then provides operation on any specific spot frequency in that particular frequency band via interchangeable crystals in the conventional manner.

By contrast the receiver and servos are conventional, except that the receiver is again of module type for the same reasons as above. In fact, with virtually all the more sophisticated radio sets, the elaboration in the form of mixed and adjustable controls is provided by the transmitter.

Chapter Nine

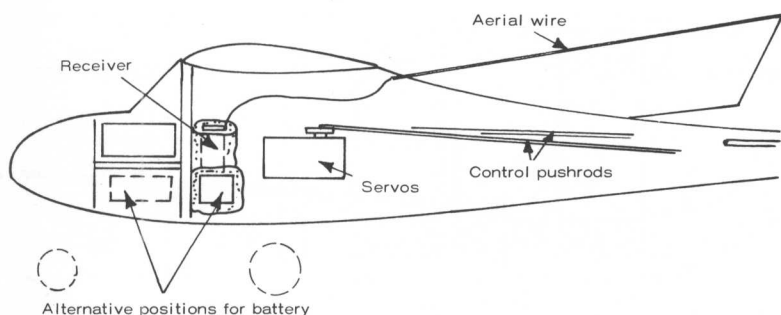
INSTALLATION—AND CONNECTING-UP CONTROLS

A RADIO-CONTROL INSTALLATION IN A MODEL comprises a receiver, battery and servo(s), with mechanical linkage(s) connecting the output movement of the servo(s) to specific control(s). Only the *servos* need to be positively positioned to resist displacement when exerting their push-pull output force. The receiver and battery can simply be placed in any convenient position, but located in some way so that they cannot move around at random with the possibility of straining leads or fouling control movements. The only other component which really needs to be fixed is the on-off switch in the wiring harness, for convenience of location and operation.

Basic installation requirements vary with the type of model, aircraft being the most demanding in this respect. In the case of a *powered aircraft* it is highly desirable to group all the radio components together around the normal, balance point of the model. The radio system may weigh up to 16 ounces complete, and if disposed haphazardly throughout the fuselage could call for unwanted ballast weight to have to be added to get the final balance point right.

Normally the plan of a radio control aircraft will show suitable positioning points for the receiver, battery and servos, the model having been designed to balance correctly with this disposition of radio gear. In the absence of such information, general rules are that the servos should be positioned under the middle of the wing position, with receiver and battery forward of this (Fig. 9.1). This ensures that in the event of a crash the strong main bulkhead can absorb the inertia of these two components and prevent them being projected forwards. To absorb any such shock loads, receiver and battery are normally wrapped in foam rubber, fitting snugly into an open box (or otherwise simply located).

A particularly effective method of mounting a receiver and its battery is to cut a block of foam rubber at least as thick as the largest component (usually the battery), and in this make two cut-outs to take the receiver and battery (*see* Fig. 9.2). The whole is then wrapped round with a piece of thinner foam rubber, held in place with rubber



9.1 Usual positioning of radio installation in aircraft

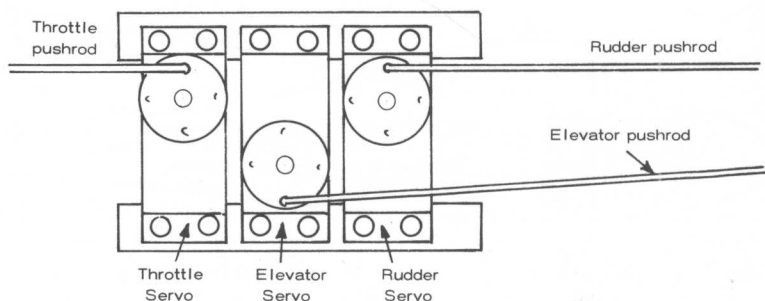


9.2 Receiver and battery mount cut from a block of foam rubber

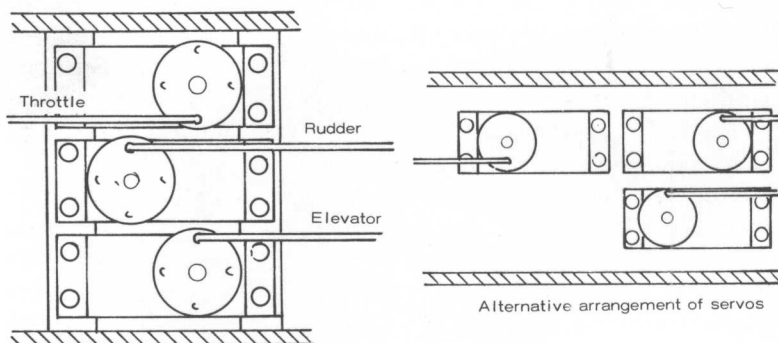
bands. The whole 'package' can then be tucked into a suitable position in the fuselage.

Alternative positioning for the battery is in front of the main bulkhead underneath the fuel tank, if there is room. This has the advantage of bringing weight forward (which is always desirable on aircraft). However, the tank compartment above it needs to be sealed off, so that spilt fuel cannot get on to the battery. Also the bottom of the fuselage needs to be reinforced to prevent the battery breaking through in a crash landing.

Rudder, throttle and elevator servos are then mounted as a group (the aileron servo is always mounted in the centre section of the wing).



9.3 Sideways mounting of servos in fuselage

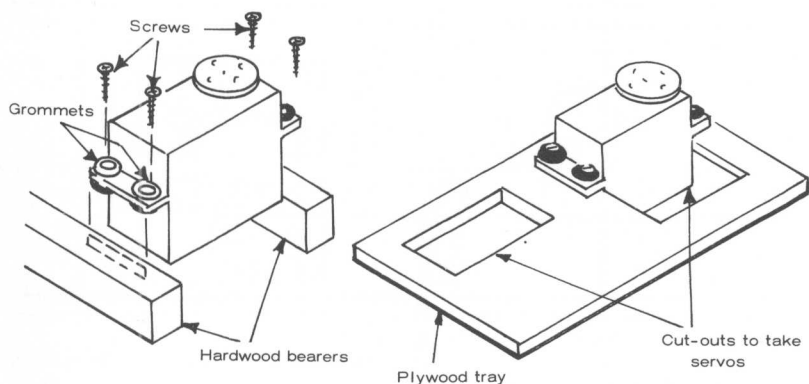


9.4 Lengthwise mounting of servos in fuselage

They can be mounted sideways—Fig. 9.3—or lengthwise—Fig. 9.4—depending on the space available in the fuselage. The main thing is to position the servos so that they give the simplest, straightest run to connect to their respective controls without the movements interfering with each other.

Servo Mounting

The servo case normally has mounting lugs with holes (or slots) to take rubber grommets. The servo is then secured in position with screws passing through the grommets, thus providing a *resilient* mounting insulating the servo from engine vibration and mild shock. The screws can secure the servo(s) to suitable spaced hardwood bearers glued inside the fuselage; or to a plywood tray with cut-outs to take the servos—Fig. 9.5. Alternatively, proprietary servo mounts



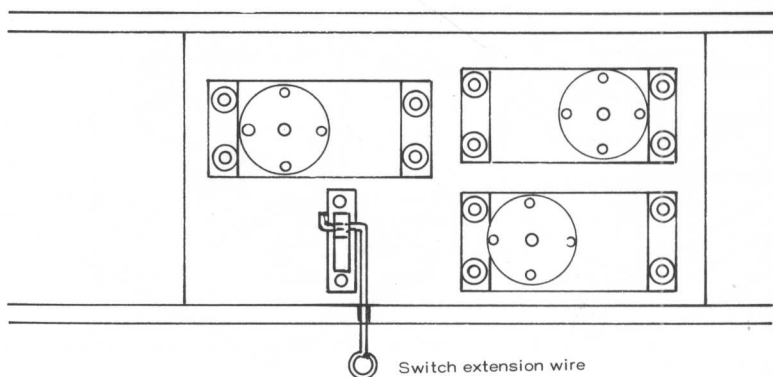
9.5 Servo mounting with screws and grommets

can be used. These are usually available for mounting one, two or three servos. The tray is fixed in a suitable position in the fuselage and the servo(s) then mounted in it, with screws.

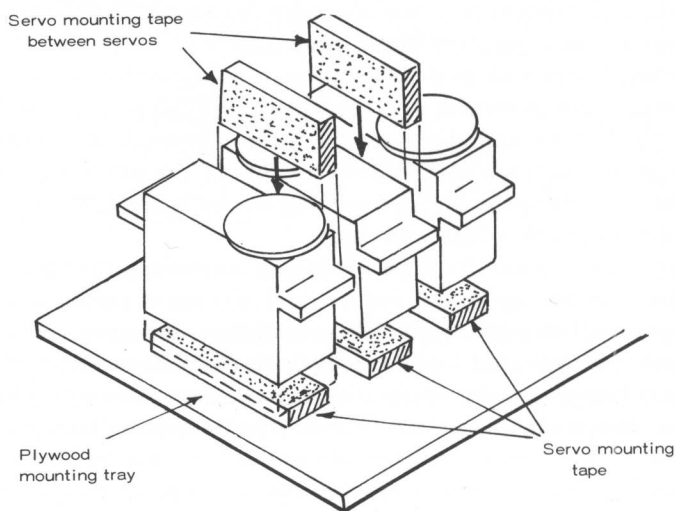
An even simpler method of mounting—and one which can provide excellent crash protection is to cut a mounting tray in the form of a deep block of expanded polystyrene fitting the whole width of the fuselage. Cut-outs are then made in this 'block' into which the servos should be a tight push fit. No mounting screws are required and the complete assembly is light and rigid.

Proprietary mounts for three servos may also incorporate a mounting position for the on-off switch (and the same feature can be incorporated in a ply tray). Many modellers, however, prefer to mount the on-off switch on the side of the fuselage, or on the top of the fuselage behind the wing. In fact, inside mounting of the on-off switch is best since it avoids any possibility of it being splashed with fuel or exhaust waste, and rain. An inside-mounted switch can easily be operated from the outside of the fuselage via a wire extension—Fig. 9.6. Many on-off switches already have a hole in the slider intended to take such an extension wire.

An alternative method of mounting servos is with *servo tape*. This is a resilient tape normally about 3/16 in. (5 mm) thick, 1/2 in. (13 mm) wide, self adhesive on both sides. Suitable lengths of tape are cut and pressed in place to the fuselage structure and the servo itself mounted simply by pressing on to the tape. Servos can be attached directly to the bottom of the fuselage, or a solid tray in this manner; or even to the

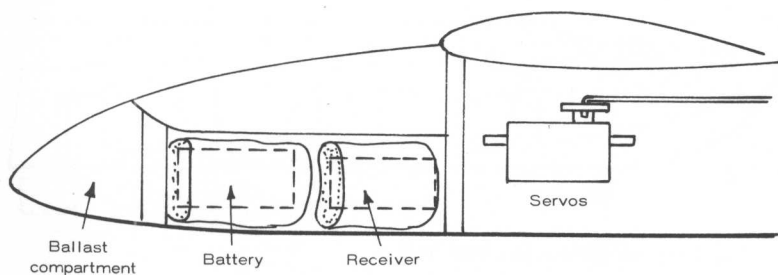


9.6 On-off switch is best fitted on the servo tray and operated by an extension wire



9.7 Servo mounting using servo tape

fuselage sides (if necessary on a balsa pad to provide sufficient clearance for the output movement). More positive fixing is ensured if the servos are mounted in a group side by side, with servo tape also being used between adjacent servos—Fig. 9.7.



9.8 Radio installation in a glider fuselage

Glider Installation

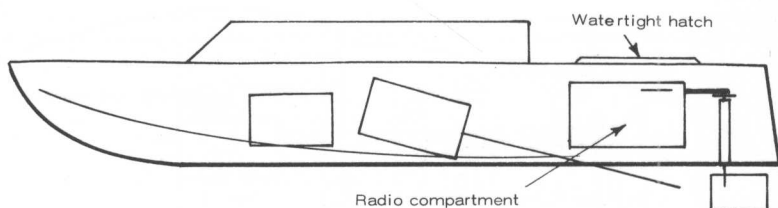
Similar considerations apply in the case of R/C gliders and sailplanes except that these models invariably require noseweight ballast to balance and so it is an advantage to mount the battery and receiver in the nose of the fuselage. This will reduce the amount of deadweight ballast required for trimming. The servos for rudder and elevator control are then mounted farther back under the wing—Fig. 9.8. If the glider also has aileron control, the aileron servo is mounted in the wing centre section.

Again the servos should be resiliently mounted (with screws through rubber grommets, or with servo tape). Whilst there are no vibration problems on gliders, resilient mounting will help absorb hard landing or crash loads.

Boat Installations

With R/C boats servos, receiver and battery can be located wherever convenient as there are usually no balance problems. However, boats operate in 'wet' conditions and water can often get inside the hull. The *best* type of installation for boats, therefore, is to group all the radio gear in one watertight compartment, or better still a watertight box, with access to this compartment through a *watertight* hatch—Fig. 9.9.

The use of a watertight compartment or box will not necessarily provide complete protection for the radio. One problem is sealing the slots in the bulkhead(s) of box side(s) through which pushrods have to pass. A fully effective treatment here is to fit elastomeric *gaiters* to the pushrods at these points. These are available as proprietary items as are watertight mounting boxes (although a plastic sandwich box will serve just as well for the latter).



9.9 Radio installation in a boat hull

The other problem is condensation. However 'dry' the atmosphere inside a watertight compartment or radio box, when the model is in a cooler atmosphere condensation can appear inside the box. Thus the hatch should be opened, or the box lid lifted, to let the radio compartment 'breathe' when the model is not in use.

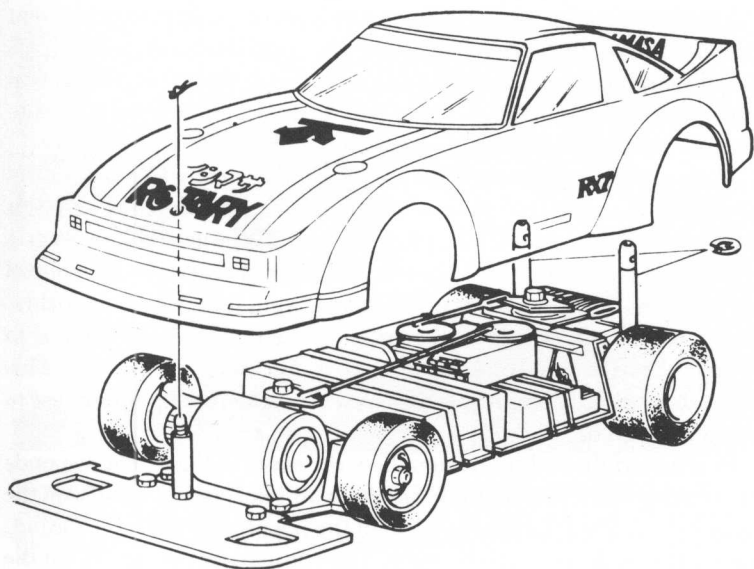
For the same reason, the alternative practice of enclosing the radio gear in a polythene *bag* secured at the neck with a rubber band is not a good one since it encourages condensation to occur within the bag.

Car Installations

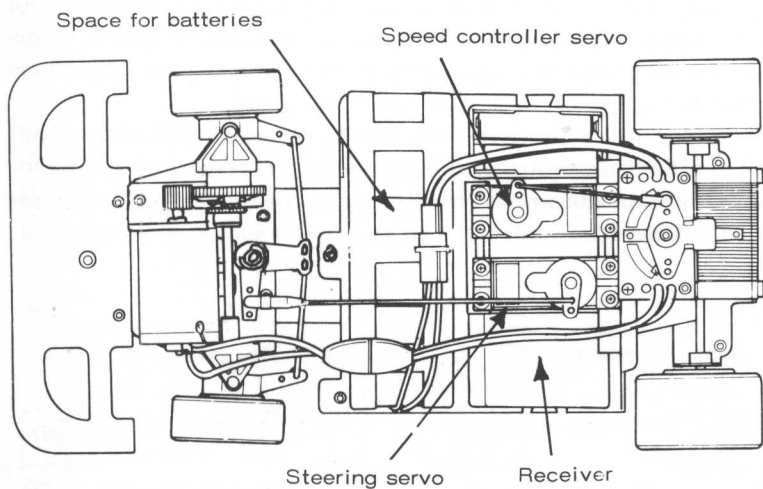
In R/C cars, particularly 1/10th and 1/12th scale models, space available within the body shell is strictly limited. It is usually a case of fitting the servo(s), receiver and battery wherever there is suitable clearance to accommodate them. Grouping of the radio gear is neither desirable nor necessary. About the only basic requirement is to keep the receiver aerial wire as far away as possible from wiring carrying current to the drive motor, in electric cars. A typical installation in a small model is shown in Figs. 9.10 and 9.11.

Connecting up Controls

Regardless of whether the servo is a *rotary* or *linear* type, servo outputs provide *push-pull* movements. Rotary servos (by far the most common type) are fitted with a disc or T-arm with a full movement of about 45 degrees of rotation either side of neutral position. This is equivalent to a push-pull movement of about 5/16 in. (8 mm) either side of neutral, of a *pushrod* connected to the outer hole—*see also* Chapter 6. Actual push-pull movement depends on the distance of this hole from the servo output spindle. Alternative hole positions may be provided to enable decreasingly smaller push-pull movements to be selected. Also, with a larger output disc or longer T-arm, a larger push-pull movement can be obtained.



9.10 Compact installation is necessary in a small R/C car



9.11 Typical R/C car installation. Unit at rear is a speed controller servo for the electric drive motor

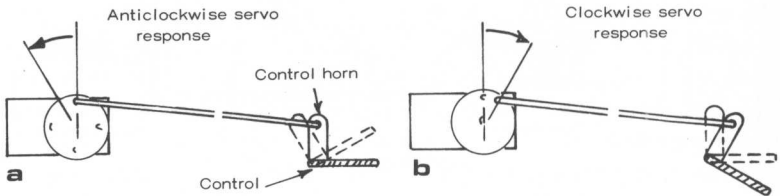
The *linear* servo provides the same sort of push-pull movement directly. It usually has two lugs sliding in opposite directions, which is useful for selecting alternative directions of movement. But the actual push-pull travel is fixed, so it can only move a pushrod about 5/16 in. (8 mm) either side of a neutral position.

Most control movements are worked in the same way. The control surface (e.g. rudder or elevator on an aircraft; or rudder on a boat) is fitted with a *control horn*. The pushrod—which in its simplest form is only a length of stiff wire—connects the servo output to the control horn (Fig. 9.12). Movement of the servo output then ‘pulls’ or ‘pushes’ the control horn, moving the control surface. The main thing is to ensure that the resulting movement is the right way round. This depends primarily on the way in which the servo rotates in response to a specific signal.

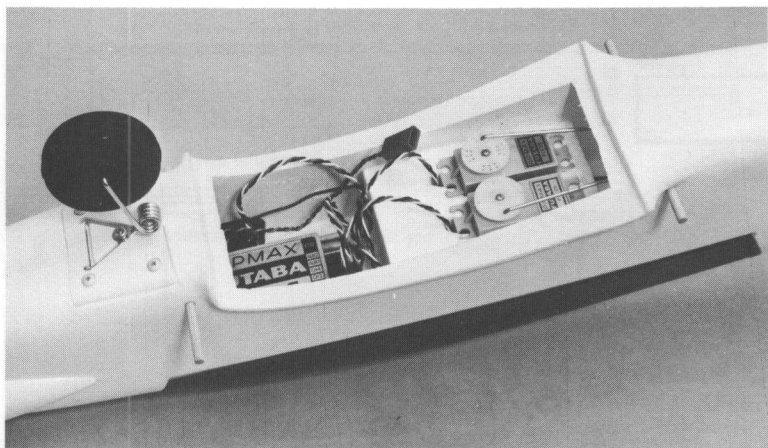
If, when ‘right rudder’ is signalled, the servo in Fig. 9.12a responds by rotating in an *anti-clockwise* direction and the control horn is on the same side as the attachment point of the pushrod to the servo output, the rudder will move to the right. The response is correct. If, on the other hand, the servo responds to ‘right rudder’ signal by rotating in a *clockwise* direction, the rudder will move to the left or the wrong way—Fig. 9.12b.

This is obviously an important point to check when connecting up controls. Make sure that the servo will produce the correct control movement, and not the *opposite* movement to that required. If the movement produced *is* opposite to that required, there are three ways of reversing it to get back to the correct response.

1. Replace the servo with one having opposite-hand rotation. (Or if the transmitter incorporates servo-reversing facility, use the appropriate switch to reverse servo response on that particular channel.)



9.12 Control movement response related to direction of servo rotation



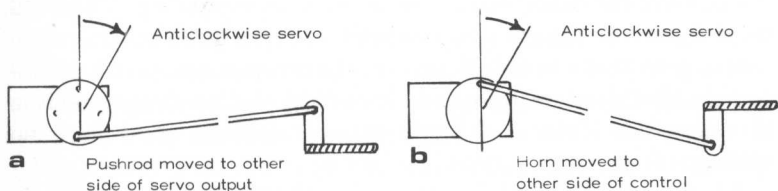
Example of 2-channel (rudder and elevator) radio installation in a model aircraft fuselage. The receiver would finally be wrapped in foam rubber and tucked into the forward compartment together with the receiver battery.

The other alternatives are two straightforward mechanical solutions, and are illustrated in Fig. 9.13.

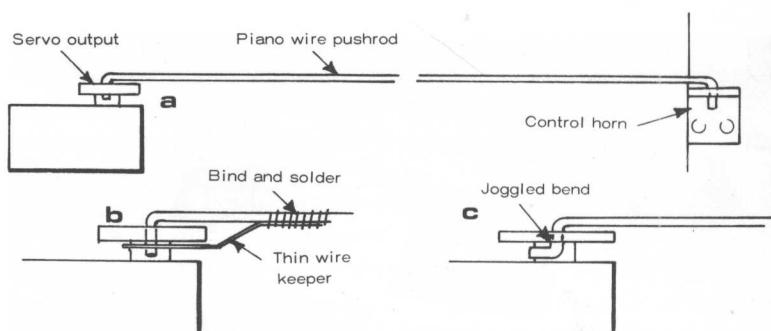
2. Transfer the pushrod to the opposite side of the servo output disc (or arm). (Fig. 9.13a).
3. Fit the control horn on the opposite side of the control surface. (Fig. 9.13b).

Types of Pushrods

16 gauge (nominally 1/16 in. diameter) piano wire makes an excellent push rod and is usually a matching (if somewhat tight) fit in the holes in servo output discs, T-arms and proprietary control horns.



9.13 Methods of reversing control movement response



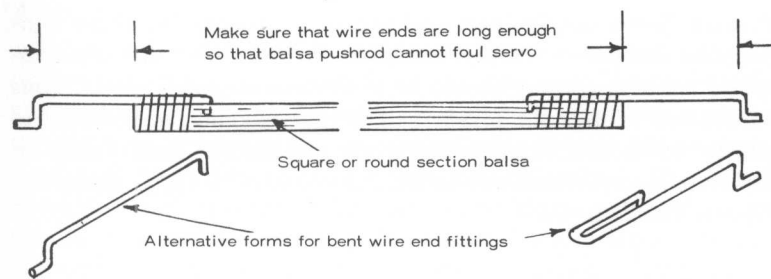
9.14 Metal pushrod with alternative end fittings

Basically all that is needed is to bend the ends of the wire sharply at right angles to fit into the servo output disc (or arm) at one end, and the control horn at the other—Fig. 9.14a. However, there is nothing to stop either end jumping out of its hole, so the addition of a *keeper* is necessary at each end. This is bent from lighter piano wire, bound and soldered in place. (Fig. 9.14b).

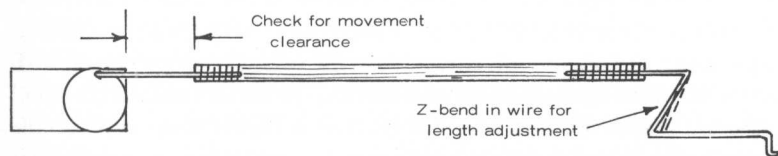
A simple alternative, which avoids soldering, is to use a 'joggled' bend in each end of the wire—Fig. 9.14c. This will provide positive location of the pushrod, but is more difficult to form properly.

Plain wire pushrods are particularly suitable for short control runs, i.e. where the servo is positioned fairly near to its control surface. If used on long runs it may need intermediate bearings or simple guides to prevent the wire bowing under 'push' loads and so losing part of its movement. Such guides should be of non-metallic material to avoid metal-to-metal rubbing contact which can generate electrical 'noise' and possible interference signals affecting the receiver. Longer wire pushrods also mean extra weight (16 gauge wire weighs about 3/16 oz. per foot). Thus to save weight on aircraft installations, where control runs are usually quite long, and obtain better rigidity, a balsa pushrod is commonly used with bound-on wire end fittings (Fig. 9.15). Here the balsa needs to be of generous section, e.g. 3/8 in. (10 mm) square on a medium size model, or better still circular section (balsa dowel) of a similar diameter. The disadvantage of balsa pushrods is that they are bulky and there may not be enough room to accommodate them at the tail end of a fuselage, particularly on gliders.

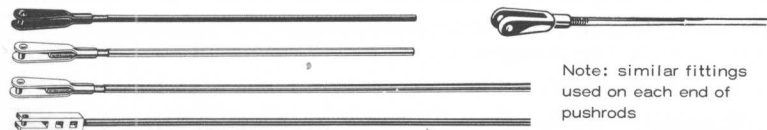
There is also one *basic* disadvantage with all simple, integral pushrods. They are not readily adjustable for length unless a Z-bend is



9.15 Balsa pushrod with wire end fittings



9.16 Simple method of adjusting pushrod length



9.17 Clevis-type end fittings for wire pushrods

incorporated in the run (Fig. 9.16). Even this is a crude method of adjustment. A much better method is to have a thread tapped on one (or both) ends of the wire pushrod on to which a proprietary clevis fitting is screwed. The clevis can be screwed on farther, or screwed out, to adjust the working length of the pushrod to fine limits (Fig. 9.17).

Clevis-type end fittings are normally only suitable for coupling to T-arm servo outputs or control horns. Fitted to a disc output the clevis may jam over one half of the movement, unless the disc is cut away to provide necessary freedom for movement.

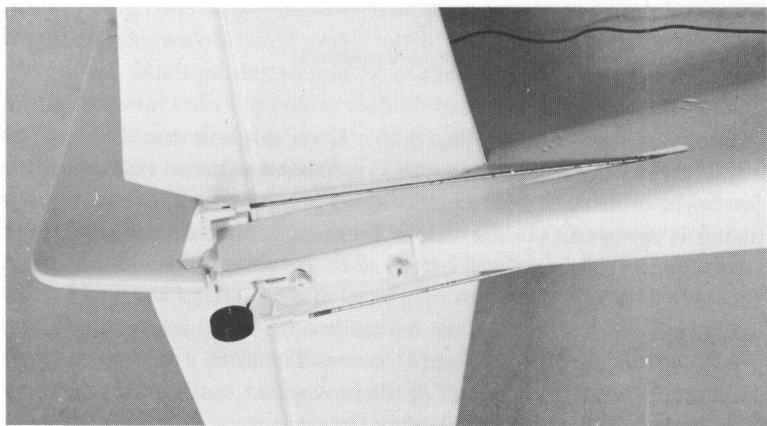
Proprietary push rods with clevis and other type end fittings are available in a wide variety of types and sizes and generally referred to as *control linkages*. Some are all-metal, some plastic with metal end

RADIO CONTROL FOR MODELLERS

fittings. Servo output discs and arms, and control horns are non-metallic (usually nylon). A basic rule to observe is that metal-to-metal rubbing contact should be avoided in control linkages. Thus metal end fittings (or plastic end fittings) should only connect to plastic horns, etc. Rudder tiller arms, and throttle control arms on R/C engines are commonly metal, and to connect to these, plastic end fittings should be used.

Snakes

A small diameter Bowden cable running in a semi-rigid tube (preferably PTFE plastic) can be used in place of a rigid pushrod for transmitting push-pull movements when fitted with suitable end fittings (e.g. clevis type fittings). This type of control linkage is known as a *snake*. It has the advantage that the control run can be curved, even doubled back on itself, and can also be accommodated in small spaces. Disadvantages are that friction is higher than with simple rigid linkage, and that the rigidity of the system is only as good as that of the free length of Bowden cable emerging from the ends of the outer tube at extreme movement positions. It would not normally, therefore, be chosen for operating controls subject to heavy 'blow-back' forces, such as elevators and rudder on larger aircraft models.



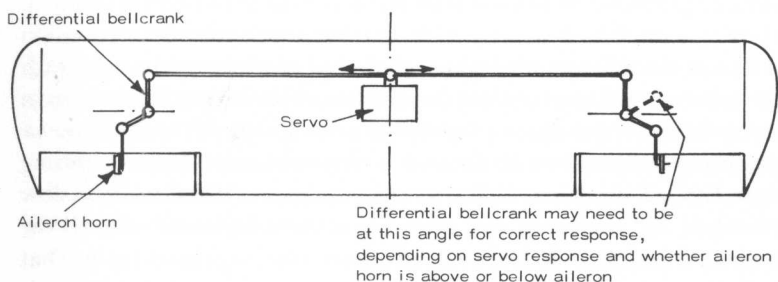
Rear end view of an aircraft with rudder and elevator controls showing the attachment of wire pushrods to the rudder and elevator horns with clevis-type end fittings.

Aileron Controls

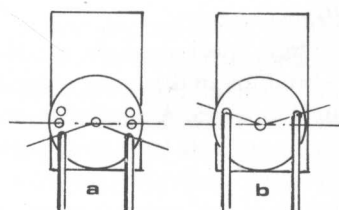
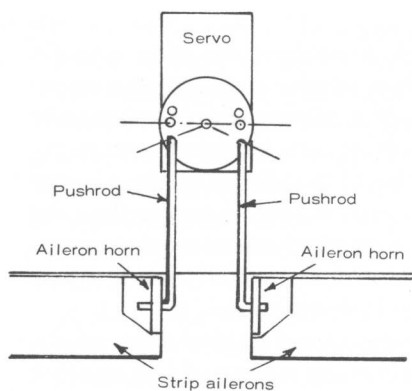
Whilst most controls are simple to connect up using a single pushrod, or snake, some controls may require more complex mechanical linkages. A particular example is ailerons, where two separate moving surfaces have to operate with opposite motions from a single servo and, preferably, movement should be differential. That is, the amount of 'up' movement on an aileron should be greater than the amount of 'down' movement. This is an aerodynamic requirement to minimize the extra drag generated by a 'down' aileron tending to pull the model round in the opposite way to that required.

A typical system for operating conventional ailerons differentially is shown in Fig. 9.18. Differential movement is generated by an offset bellcrank with a short pushrod connecting to the aileron horn at each aileron position. The two bellcranks (one in each wing) are themselves moved in an opposite manner to each other by long pushrods connecting to the same (or substantially the same) point on the centrally mounted servo. The whole of this linkage, with the exception of the aileron horns and the emerging aileron pushrods connecting to them is contained within the wing.

A much simpler system can be used with *strip ailerons* (Fig. 9.19). A rotary servo is mounted in the wing centre section connecting via short pushrods to control horns on the inboard end of each strip aileron. Differential movement is obtained by connecting the pushrods at hole positions aligned at an angle to the normal hole positions, giving more *actual* push-pull movement one way than the other. Whether the hole positions have to be 'angled forwards' or 'angled back' depends on whether the ailerons' horns are above or below the aileron—see detail in diagram.



9.18 Control linkage for differential aileron movement



For servo response clockwise when 'left' signalled, use position A if horns are on top of aileron; or position B if horns are below aileron.

For opposite servo response, use position B if horns are on top of aileron; or position A if horns are below aileron.

9.19 Obtaining differential movement with strip ailerons

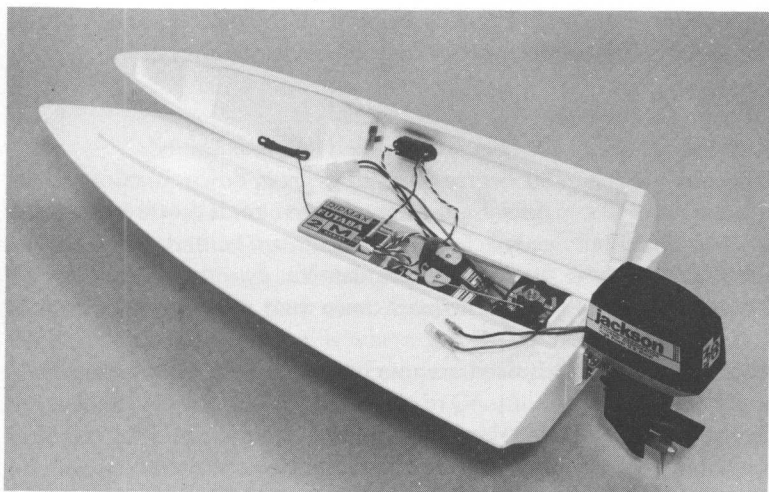
Many rotary servo output discs already incorporate these 'angled hole' positions. If not, they will have to be drilled in the disc on a line at an angle of about 15 degrees from the normal line of holes.

A final point with aileron controls. It is important to choose a servo which gives the right direction of response. If not, the only solution will be to reposition the control horns on the opposite side of the ailerons in order to get correct movement.

Control linkages incorporating bellcranks or similar intermediate mechanisms may be needed to operate other types of controls but these are generally specific to the individual type and design of model concerned and outside the scope of this particular book.

Adjusting Controls to Neutral

With screwed-on end fittings it is a simple matter to adjust control surface positions to neutral with the servos in their neutral position. Here it is important to remember that the true servo neutral position is that position it assumed when connected up to the receiver and with transmitter and receiver *both* switched *on*. A servo can, in fact, stop in three different positions (depending on whether the transmitter or receiver was switched off first when last working). With everything switched off, the servo will obviously not move. If the *receiver* is now switched on, the servo will probably move a little and stop. If the *transmitter* is then switched on, it will move a little again and stop. That is the true servo neutral position as far as operation of the system is concerned.



Compact 2-channel radio installation in a fast electric boat. One servo operates outboard motor steering; the other a potentiometer-type speed controller for this motor.

Adjusting Control Movements

This again is basically quite straightforward. It is simply a matter of re-positioning the pushrod in a different hole either in the servo output or the control horn.

To Increase Control Surface Movement

Reposition the pushrod in a hole nearer the inner end of the control horn. Alternatively, if you are not already using the outer hole in the servo output disc or arm, move the pushrod to this position.

To Decrease Control Surface Movement

Reposition the pushrod in a hole nearer the spindle on the servo output disc or arm. Alternatively, if you are not already using the outer hole in the control horn, move the pushrod to this position.

Remember that adjustment of control movement in this manner will also call for a readjustment of pushrod length for the same (original) neutral position.

Control Movements Required

The following can be taken as a general guide to actual control

RADIO CONTROL FOR MODELLERS

movements required. These can vary with the type, size and operating speed of the model, particularly in the case of aircraft.

Aircraft Controls:

- Rudder — 30 degrees right and left, maximum
- Ailerons — 30 degrees up, 20 degrees down, maximum, for rolls. Less aileron movement is required for turns only.
- Elevators — 10 degrees up and down.
- Flaps — 30–35 degrees down (not more than 45 degrees down)

Trim movements required are much smaller, otherwise trim control will be too coarse.

- Rudder trim — 1–2 degrees right and left
- Elevator trim — $2\frac{1}{2}$ degrees up and down, maximum
- Ailerons — 3–5 degrees up; $1-2\frac{1}{2}$ degrees down.

Boat Controls

Maximum rudder movement should not exceed 30 degrees right and left and in most cases should preferably be less. A good starting point is $22\frac{1}{2}$ degrees right and left, equivalent to a rudder tiller arm length of *twice* the distance of the servo disc or arm output hole from the servo spindle.

Chapter Ten

SAVING A SERVO OR CHANNEL

SERVOS IN SOME CASES can cost almost as much as a Tx-Rx Combo, so in a multi-channel installation the total cost inevitably mounts up. As a basic rule, though, all *main functional controls* on a model should *always* be operated by their own separate servo. The only real justification for 'saving a servo' is where you do not have the number of channels on your Tx-Rx Combo to operate all the controls you want to (or have failed to follow the advice in Chapter 3 and Chapter 7!).

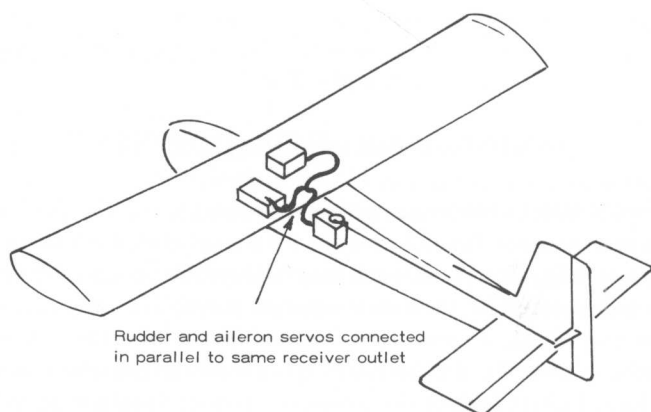
If you have run out of available channels before you have covered all the *functional* controls, then you can get around this by using coupled controls. This is most likely to happen with aircraft where, say, you have started with gliders and a 2- or 3-channel Combo and want to go on to powered aircraft. In this case you can work *two* controls from *one* servo to get round the immediate problem—but it will still be only a compromise. The main thing is to pair up or couple controls which *can* successfully be operated simultaneously, or can be *decoupled* for working independently. The choice is somewhat restricted.

There is another form of 'coupling' used on some aerobatic aircraft, namely coupled elevators and flaps. In this case the coupling is purely *mechanical*, i.e. elevator movement *always* produces flap movement as well. This can produce better response to elevator control, with tighter manoeuvres.

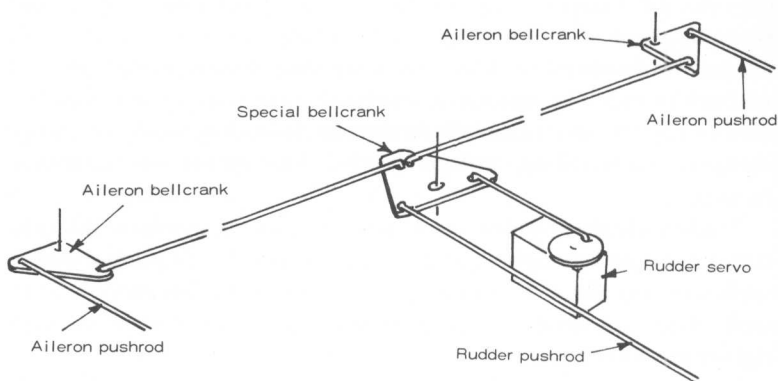
In terms of normal 'full house' coverage for aircraft, controls which can be coupled are:

1. ailerons and rudder
2. elevator and rudder

The former is by far the better proposition (unless you are stuck with a 2-channel Combo and want to try to achieve 3-channel coverage). Throttle should be left as a separate control, not coupled to another, although it can be used for *decoupling* (see later). The big disadvantage with coupled ailerons and rudder—apart from limitations on flight control (you do not always want to use ailerons and elevator together)—is that it is difficult to couple aileron and rudder linkage to the same servo successfully. The most satisfactory method



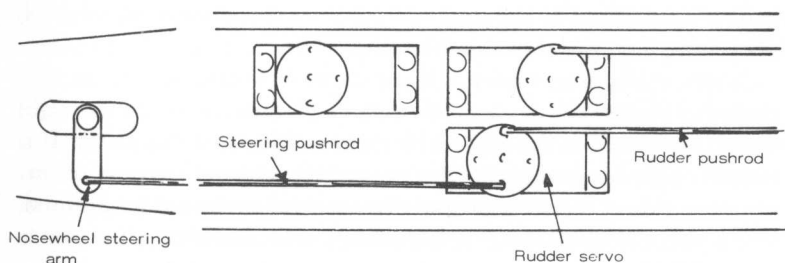
10.1 Coupled aileron and rudder controls using two servos in parallel connection



10.2 Mechanical coupling of ailerons and rudder working off one servo

with coupled aileron and rudder is to use a separate servo mounted in the centre section of the wing and connected to the aileron linkage; and connected in parallel electrically with the rudder servo (Fig. 10.1).

But that does not save a servo—so if that is the intent, mechanical coupling must be used. The basis for such a system is shown in Fig. 10.2. A bellcrank counted in or under the wing centre section carries both the aileron pushrods and the rudder pushrod; and is itself connected to the servo output via another pushrod. The problem lies



10.3 Nosewheel steering with direct mechanical coupling to the rudder servo

in devising a suitable location for the servo with a mechanical hook-up which can be disassembled to remove the wing for transport without distorting or bending the pushrods. The rudder pushrod (at least) must be readily detachable to remove the wing. Quite likely, too, there will not be enough room in the wing to accommodate both the bellcrank and the servo; so the servo will have to be mounted in the fuselage and its pushrod also made detachable.

Coupled ailerons and rudder can work quite well on gliders, giving rudder, elevator and aileron control from a 2-channel, 2-servo outfit, for example. The optimum amount of rudder movement required can only be set up by trial and error, i.e. trying different positions for the pushrod connection to the rudder horn.

Coupled ailerons and rudder (with throttle and elevator control also available) are usually less successful on a powered aircraft—and optimum rudder movement more critical. It would be safest applied to a model with reasonably generous dihedral (i.e. a typical 3-channel Trainer); but with such a type the ailerons will be least effective as a control. In other words, the model may not handle any better than with straightforward rudder, elevator and throttle control.

Undercarriage Steering

One coupled control which is always acceptable is mechanical coupling of nosewheel steering to the rudder servo—Fig. 10.3; or tailwheel steering directly to the rudder movement. This is normal practice (although not all R/C aircraft do have, or need, undercarriage steering). Either system is easy to install, except that with a steerable nosewheel it is highly desirable to have some form of shock absorber in the linkage between the nosewheel steering arm and the rudder servo. With a rigid pushrod, heavy shock loads could be

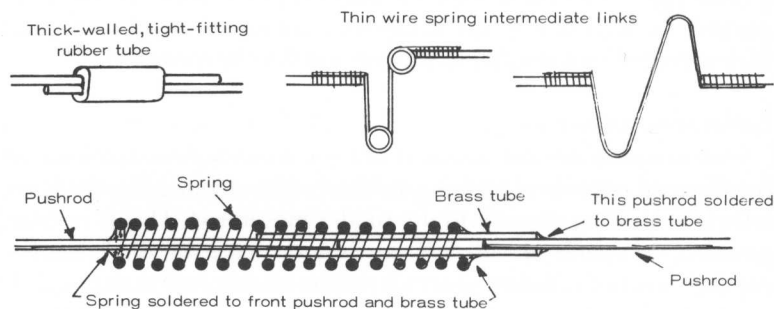
transmitted direct to the servo output movement. Example of shock absorbing links are shown in Fig. 10.4.

Another important point with nosewheel steering is to make sure that the nosewheel movement turns (and thus steers) in the right sense, i.e. steers to the right with right rudder, and vice versa. It is usually best to arrange for the nosewheel pushrod to come off the opposite side of the servo output disc (or arm) to the rudder pushrod, when the nosewheel steering horn needs to be on the opposite side to the rudder horn.

'Full House' plus on 4-channels

'Full house' or 4-channel operation of powered aircraft allocates one servo each for rudder, elevator, ailerons and throttle control. Secondary control services can be added to this, still using a 4-channel Combo, a typical example being a retractable undercarriage. A separate (retract) servo works the retract/extend undercarriage movement, itself being controlled by a switch operated by 'trim' movement(s) of one of the main servos (almost invariably the throttle servo).

Such a system is shown in Fig. 10.5. On the transmitter, throttle control is normally used with the throttle *trim* backed right off. In the model itself, a changeover switch is positioned close to the normal full throttle movement of the throttle servo. Throttle control is used normally, ignoring throttle trim. To operate the retract servo the throttle is moved to full throttle position *and* the throttle trim advanced. The additional throttle servo movement then actuates the changeover switch, completing the retract servo circuit through a



10.4 Shock links which accommodate differential pushrod movement. These are also often used on the throttle pushrod

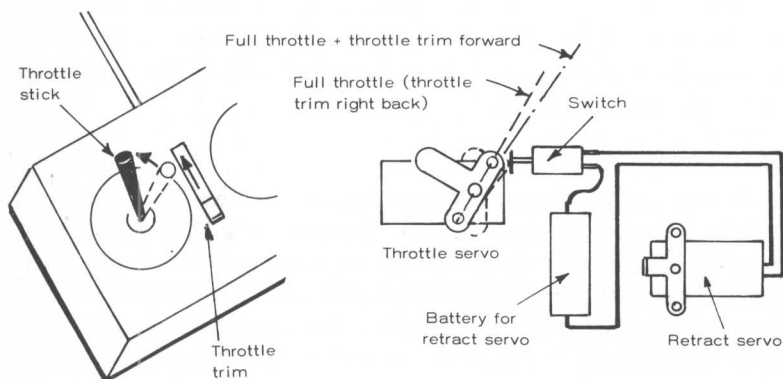
separate battery to retract the undercarriage. Throttle trim is then backed right off and throttle control used normally throughout the flight.

When the time comes to extend the undercarriage, full throttle is selected plus forward movement of throttle trim. The retract servo circuit is again completed through the changeover switch to reverse its output movement and lower the landing gear.

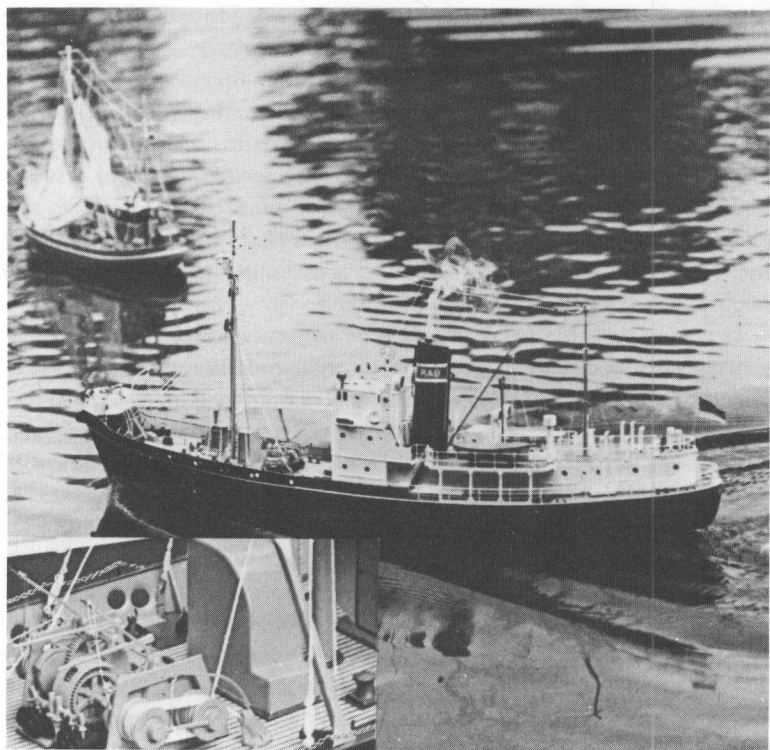
The only real limitation in this system is that it utilizes *trim* movement for an additional control, so this is no longer available as a 'stop engine' control as described in Chapter 4.

It is also possible to work this type of secondary control through switches from extreme movements plus trim on other servos; and even from *both* ends of a servo movement (i.e. leaving the trim control in the central position for 'neutral' as far as the secondary service(s) are concerned. Thus a retract servo could be operated at one end of a movement (say full throttle plus trim movement); and a similar servo could operate flaps at the other end of a movement.

Since utilization of a 'trim' movement as a separate control inhibits use of trim with that particular (main) control, normally only the throttle servo would be used in this manner. But switched systems, particularly flap operation, can successfully be linked with elevator servo trim. As a general rule, though, the more complex any system of switching additional servos via main servo trim movements becomes, the more unreliable it can become, and the more restrictive on the use of main controls. It is always the main functional controls which



10.5 Principle of additional control operation actuated by a trim control

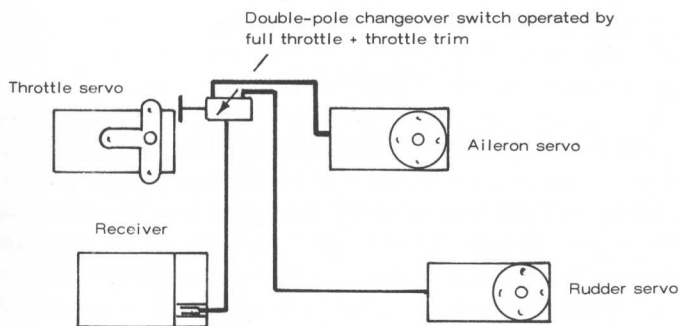


Boats are always a fascinating subject for radio control. They are the 'safest' subject since they are seldom likely to be damaged through loss of control.

matter most, so any '4-channel plus' system can never hope to be as good as a 5-channel or 6-channel system working the additional servo(s) required directly.

Decoupled Controls

A very similar system of switching can be used to operate two servos from one control channel, but one at a time rather than coupled. In this case the switch operated by the throttle servo at full throttle plus trim movement is a double pole changeover type. The two servos are connected in parallel to the *same* receiver outlet (same control channel), but through the switch. Thus depending on the switch position, either one or the other servo is effectively connected to the receiver, and thus responding to control command (Fig. 10.6).



10.6 Principle of decoupled control operation

The paralleled servos would normally be rudder and ailerons, giving rudder, elevator, ailerons and throttle connected to a 3-channel receiver. On the basis that rudder control is used least of all with 'full-house' control coverage, but it is still *essential* to have available, this would be the servo selected for take-off. After take-off, at full throttle, forward movement of throttle trim now changes over the 'rudder' channel to operate ailerons. Throttle trim can then be left where it is to provide aileron control (with no rudder) for all throttle settings less than full throttle, with immediate reversion to rudder control (no ailerons) if full throttle is given; or trim backed off to give control changeover at full throttle *plus* trim movement. The latter is better as it cannot give accidental changeover. But neither system is a recommended one, and certainly not for learning purposes since it puts rudder and ailerons on the same stick.

Chapter Eleven

AERIAL PHOTOGRAPHY WITH MODELS

THE RADIO-CONTROLLED MODEL AIRCRAFT is an excellent vehicle for aerial photography. In fact, apart from its use in this way by enthusiastic amateurs, it is increasingly being employed professionally for aerial survey work. The particular attraction here is the substantially lower cost of operating a radio-controlled model compared with hiring a full size aircraft with pilot and camera man aboard!

To explore possibilities in aerial photography the requirements need studying under three main headings—the model, the camera and the technique.

The Model

Logical choice would be a large 'trainer' type or sports type high wing cabin-type model (even a scale model) with a generous wing area and low wing loading. Bearing in mind that it has to carry the weight of a camera as well as radio gear—and still end up as a slow flying model—a wingspan of 6 to 8 feet should be about right, depending on the size and weight of the camera. Suitable engine sizes would then be 0.40 to 0.60 cu.in. capacity.

It is important that the model has a good low speed performance, a good glide, and is easy to fly. A large glider would meet these requirements, but gliders have to be towline- or bungee-launched to reach a suitable height when operated from flat ground. Thus a power model is by far the more logical choice for any serious aerial photography work.

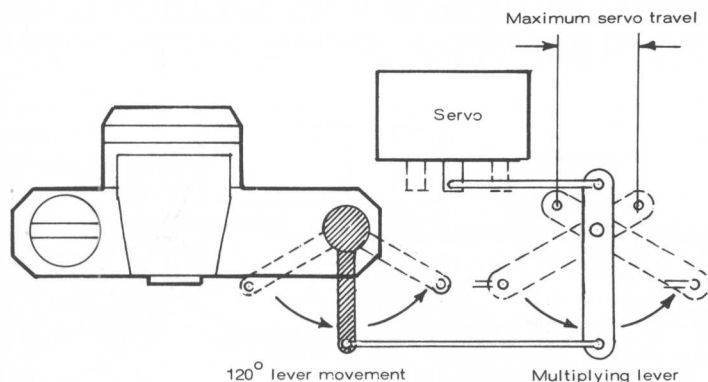
Due consideration must also be given to the type of terrain the model is to be *operated* from. Some of the more interesting sites of aerial photography may have no suitable take-off and landing areas near them. In that case the model may have to be hand launched; and be capable of landing in a short distance without damage, even, perhaps on a cart track or in a stubble field. This again emphasizes the desirability of a slow flying model. The fact that such a model may not be so easy to handle in strong winds is not significant. Windy weather is not the best time for taking aerial photographs.

The model will need to have 'full house' controls—rudder, elevators, ailerons and throttle—plus 1 or 2 more radio channels available, i.e. 5- or 6-channel radio. Camera control(s) *must* be independent of the flight controls. The choice of camera will determine the number of extra controls required, i.e. an auto-wind camera will only require one channel for working; a manual wind camera one channel for film winding and another channel for operating the shutter.

The Camera

Here the ideal choice is a camera with motor drive or clockwork auto-wind as this will be by far the simplest to rig for consistent, reliable operation using only one servo. Cameras with *lever wind* present mechanical problems. Lever movement required to wind on is usually at least 120 degrees, and may be more. The *full* output movement of a rotary servo is never more than 90 degrees; and that of a linear servo no more than $\frac{3}{4}$ in. (19 mm). Multiplication of servo output movement through a lever system is easiest with the latter type, e.g. as in Fig. 11.1—but not necessarily a practical solution. (Note, the servo in this case would be operated by a *non-proportional* channel so that it ran from one extreme position to the other when signalled; and then fully return when the command signal is released).

If a lever wind camera *is* to be used, then probably the most practical solution is for the servo to drive a simple ratchet mechanism



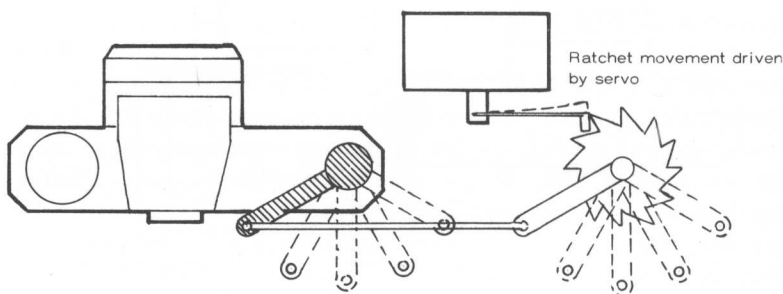
11.1 Lever wind-on operated by linear servo via a multiplying lever movement

to allow several strokes of the servo to be made to wind on each frame, although the resulting 'mechanics' can be somewhat tricky to design and make (Fig. 11.2). It has to protect the servo from being stalled on the final stroke, and allow the camera lever to return fully to its initial position after completion of the stroke with the servo reverting to its neutral ('off') position.

Where film advance is by a knob on the camera the solution can be simpler, e.g. a rack-and-pinion or even a friction plate drive from the servo, depending on the amount of effort needed to turn the knob. One camera which is a relatively easy subject to treat in this way is the Olympus Trip, which has a thumbwheel wind on.

All this emphasizes the superiority of the auto-wind or motor drive camera for simple installation! It needs only a simple movement to depress the shutter release. (Other types of cameras require this in addition to wind-on movement). This can be a simple bellcrank movement operated directly from the servo and bearing directly on the camera release button or against the end of a cable release (Fig. 11.3). The latter has the advantage of allowing the servo to be mounted separately from the camera. Alternative hole positions on the bellcrank arm carrying the servo pushrod provide movement adjustment, i.e. to give the necessary shutter release movement with *full* movement of the servo (to avoid stalling the servo). Alternatively, the servo pushrod could incorporate a slip link, as in engine throttle controls.

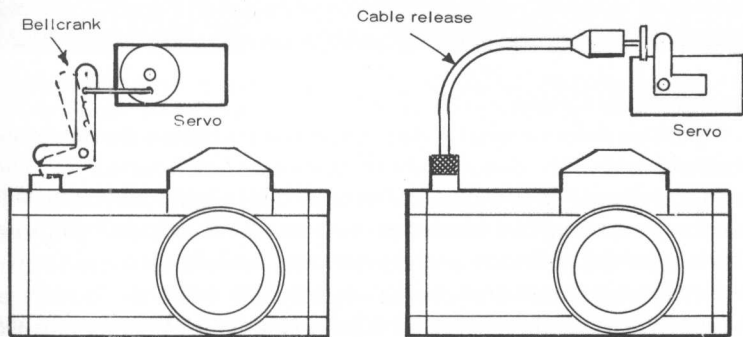
An even more compact arrangement is shown in Fig. 11.4 where the servo is mounted directly on the camera, above the shutter release, and fitted with a specially shaped and proportioned servo



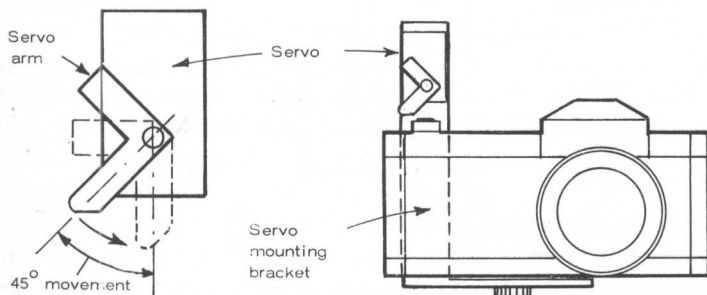
11.2 Ratchet movement can operate lever wind-on in a series of steps

arm to bear down on the release button. Length of this arm is trimmed to provide 'full' shutter release movement with full servo movement.

Compact 110 cameras are attractive because of their small size and weight, and many are now available with motor drive. However, the negative size is only 25 per cent of that of 35mm film and picture quality is invariably inferior. (Also the choice of film types and speeds is strictly limited). Thus the average 110 size camera is not really worth considering for serious aerial photography, with the one (present) exception of the Pentax 110 which has an excellent optical performance and interchangeable lenses (but with the same 110 film limitations). It could be a logical choice where camera size and weight must be reduced to a minimum, but is as expensive as a good 35mm SLR camera (with the advantage of larger negative size and wider choice of film).



11.3 Camera shutter operation via a simple bellcrank or L-shaped servo arm



11.4 Mounting the shutter operating servo on the camera is recommended practice

RADIO CONTROL FOR MODELLERS

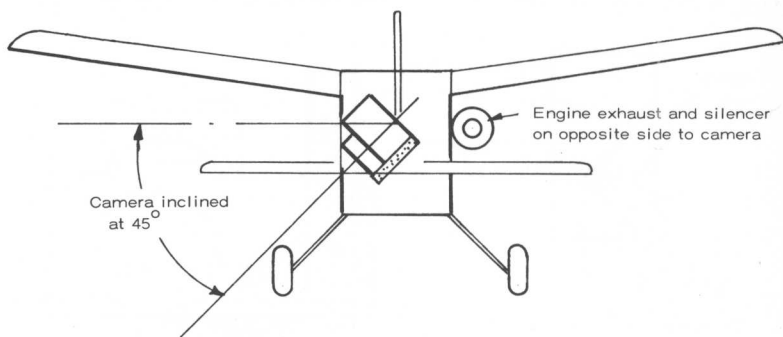
Automatic exposure cameras tend to select shutter speeds which are too slow for satisfactory aerial photography. Basically this means that they should be used with fast films for best results; or if slow films are used (e.g. colour films), photographs should be taken when gliding rather than under power. On the other hand a camera with normal settings made on the ground may be way out when the exposures are finally made at a height—with no means of checking, or altering the settings to compensate, until the film is developed.

Focusing is straightforward, however. Focus should be set to infinity. Auto-focus is quite unnecessary and if the camera has this feature the auto-focus 'window' should be covered over with tape so that the camera will focus on infinity each time.

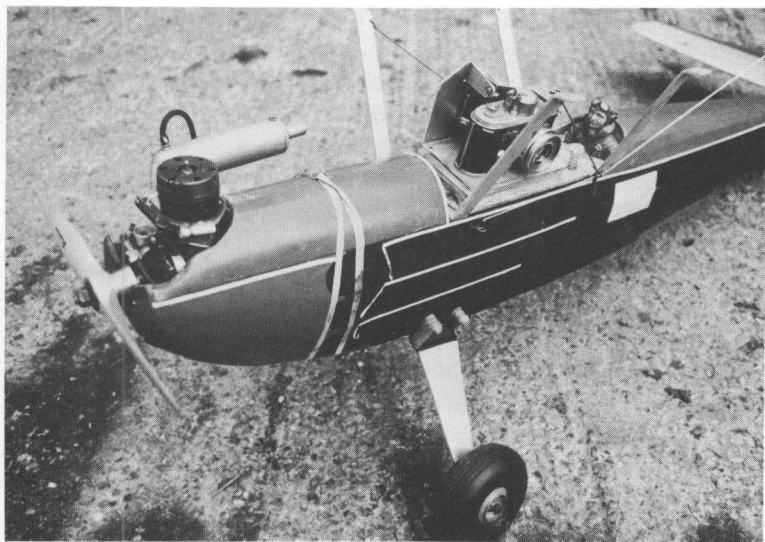
Given a choice of lenses, a medium wide angle is best (e.g. 35–40mm). A 50mm lens, 'standard' on most 35mm SLR cameras would be suitable. A larger focal length lens should not be used on a 35mm camera. If you need a larger image you will almost certainly get better results by enlarging up from a negative taken with a 35 or 50mm lens.

Positioning the Camera

Opinions differ on what is the best position to mount the camera—pointing vertically downwards or sideways and downwards. The former will give 'horizontal' pictures in level flight. The latter will need to be turning in a banked attitude to take 'horizontal' pictures. Of the two the 'sideways and downwards' positioning seems to give the most scope and best results—specifically when the camera is mounted at an angle of about 45 degrees (Fig. 11.5). Photographs are



11.5 Sideways and downwards mounting of the camera usually gives the best pictures



Robot Star camera (featuring clockwork wind-on) installed on a Barnstormer—one of the models used by Peter Miller to take the aerial photographs included in this chapter.

then normally taken when the model is in a banked attitude and since, as a general rule, left hand turns are easier to fly than right hand turns, the camera is best mounted pointing out of the left hand side.

This also agrees with the normal arrangement of model aero engines where the exhaust is on the right-hand side—hence the right side of the fuselage tends to get splattered with oily exhaust. It is essential to mount the camera in a clean area (i.e. the opposite side to the exhaust, with an unobscured view for the lens pointing out through an aperture in the fuselage, e.g. a panel devoid of covering). When deciding the mounting position bear in mind the picture angle of the lens used—normally about 60 degrees for a 35mm lens and about 45 degrees for a 50mm lens. Any parts of the aeroplane itself within this picture angle will, of course, appear—out of focus—on every picture taken.

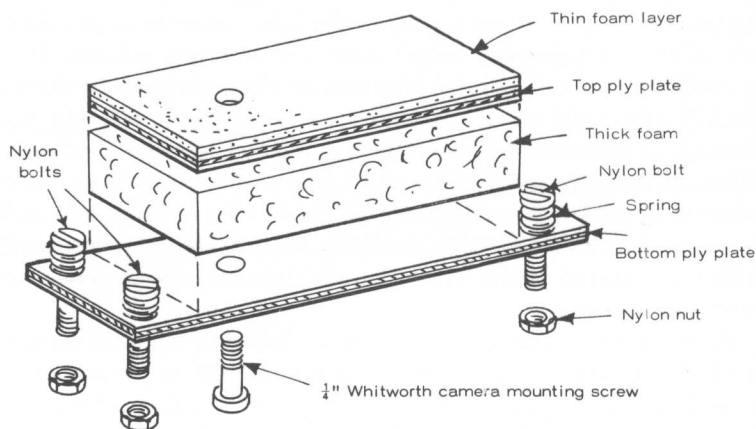
With the requirement that the camera should be mounted around the balance point of the model, which is about 30–40 per cent back from the leading edge of the wing, a high wing layout is about the only type of model which can accommodate such 'sideways and downwards' mounting. Mounting a camera in a low wing model limits

positioning to vertical (downward) mounting, with additional structural snags. (The aileron servo is normally mounted in the wing centre section, for example). The alternative is to mount the camera farther aft (with the possibility of making the model tail heavy), pointing backwards as well as downwards. Nevertheless there are examples of low wing and similar model types being adapted for successful aerial photography. Basically, though, there is no reason to make the job more difficult than it needs to be. The simplest solutions are usually the best, using a model type and camera best suited for the job. For the latter reason it is best to buy a camera which *is* suitable for the job, rather than try to use an existing one you may have, but which is seen to have many limitations.

Mounting the Camera

A mounting is required to isolate the camera from vibration, and at the same time hold it quite steady as well as providing protection in hard landings. The type of mounting used by a leading U.K. expert on model aerial photography is shown in Fig. 11.6.

This consists of two pieces of 1/18th ply with about 3/4 in. (19 mm) foam rubber between them, stuck down with contact adhesive. The lower plate is bolted to the model with either Dzus fasteners or long nylon bolts with springs under the head. The camera is mounted to the upper plate via the normal tripod bush (1/4 Whitworth thread)

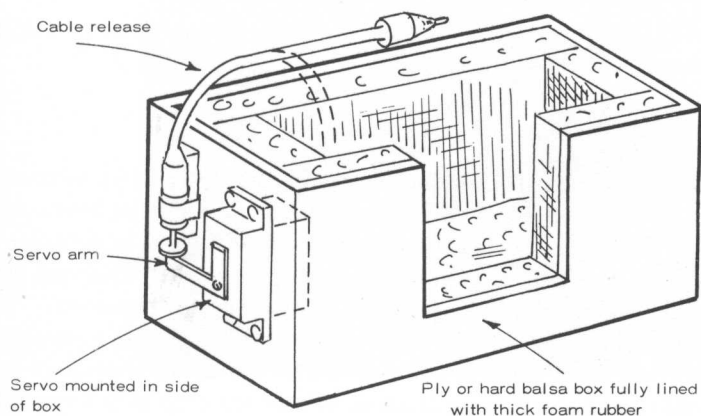


11.6 Example of a well designed camera mount

with a thin layer of foam under the camera to prevent it twisting on the plate and to protect the bottom of the camera. The servo that operates the shutter release should be mounted on the same plate as the camera to avoid any possibility of vibration being transmitted through the operating mechanism while the shutter is being operated. A simple bellcrank type lever that presses on the shutter release button is all that is needed but some method of adjustment must be incorporated, either a screw at the shutter release end or a clevis at the servo. Foam pads can be placed forward of the camera for crash protection.

Much simpler mounts can also prove satisfactory, e.g. a simple box of ply or balsa generously lined with foam rubber (or even foam-backed carpet)—Fig. 11.7. Here, since the camera ‘floats’ in its mounting (which itself can be further protected by foam pads), the operating servo should be mounted *on* the camera, unless the shutter release is triggered via a cable release.

An even simpler system, which the author has found very satisfactory, is to cut a box-type mount from a slab of expanded polystyrene into which the camera sits. The original moulded foam packing provided when the camera is first bought can often be retrimmed and joined together to make such a mount. The operating servo can be mounted separately, working a shutter release cable.



11.7 This type of camera mount is easy to make. It is best used with a cable release, although the servo could be mounted on the camera as shown in Fig. 11.4.



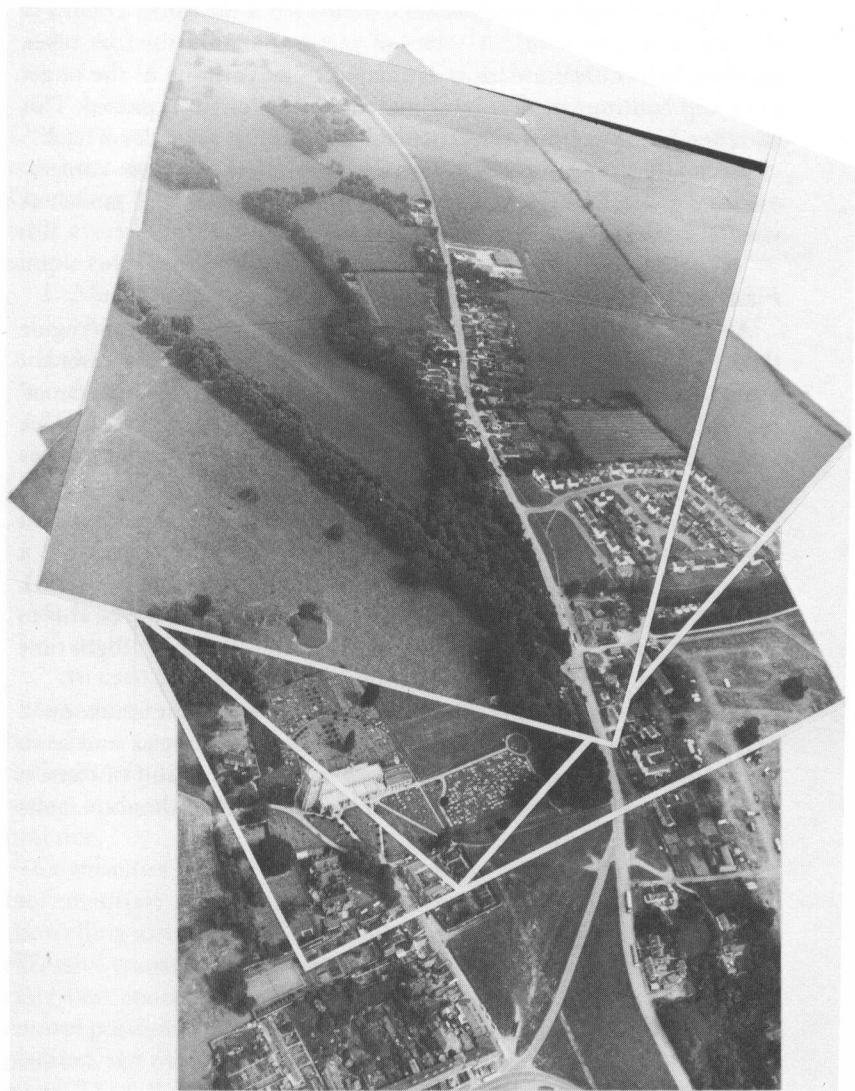
Long Melford Hall (Suffolk) taken from a height of about 800 feet on a bright sunny morning. (Peter Miller).

Technique

Much depends on what you want to photograph and where you are operating from. Also choice of a suitable day is important. Best results are usually achieved on completely cloudless days. The presence of patchy clouds can give less than perfect exposures. Overcast skies usually produce relatively poor results—and grainy negatives.

For 'aerial survey' work, photographs need to be taken from a good height, e.g. from 1,000 feet or even more. A moderate wide-angle lens should then cover an area of about $\frac{1}{2}$ mile from top to bottom of the frame. For other subjects you may need to photograph from much lower altitudes.

With a 'sideways and downward' mounted camera you need to



A typical sweep of four photos, the close spacing of the shots showing the fast wind of the camera and slow rate of turning of the model—both essential features to get a particular target in a reasonable position on the film. (Peter Miller photographs).

climb to the best height and then put the model into a gentle banked turn with the engine throttled back (to the left if the camera points to the left, and *vice versa*). A series of pictures should then be taken starting before the camera is estimated to be pointing at the target area and continue until it is estimated that the target is passed. This can then be repeated at different heights and different angles of bank.

Remember *always* to make a pre-flight check that the camera-operating mechanism is working before launching the model. A wasted frame is far cheaper than a wasted flight!

Films and Flying Speeds

As far as possible always take photos at slow flying speeds (engine throttled back). Filming at high engine revs can produce resonant vibrations which will blur the image, even with 'vibration-proof' mounting of the camera. With a good quality camera, 125 ASA black and white film (e.g. PAN X or FP4) should produce excellent results. You can, of course, use faster film if you wish, but this can result in more grainy negatives, particularly in duller conditions. For best results with slower colour films, throttle the engine right back into a powered-glide condition, or even a glide with the engine stopped. Remember, if you do stop the engine in the air you will not be able to re-start it, so you only have a limited amount of (gliding) flight time remaining to complete taking your photographs.

Finally, remember one other basic rule—if you want to take good aerial photographs you must use a good quality camera and fresh film. If results are poor you will then know it is a fault of camera mounting or technique, not the equipment itself. And these are faults that can be rectified.

Chapter Twelve

OPERATING RADIO CONTROLS

ONLY PRACTICE WILL MAKE PERFECT—or as near perfect as you can hope to get—in the operation of any radio-controlled model. Operating the *radio* is simplicity itself. Virtually switch on and go, with every confidence that it should work properly provided a few simple rules are observed.

1. Make sure that the Tx and Rx batteries are fresh, or fully charged.
2. Make sure that the transmitter aerial is fully extended and firmly attached to the transmitter.
3. Make sure that all the control movements are working properly and responding to the transmitter control movements.
4. Do not try to operate the model if any of the controls are not responding properly.
5. If everything is not working properly, *see* 'Radio Trouble-Shooting' (later) to identify and rectify the fault.
6. If operating in company with other R/C modellers, make sure that the 'spot' frequency you use is different from those already in use (*see* Appendix 2).

Learning to become an R/C aircraft pilot, R/C car driver, powerboat driver or yacht helmsman is not quite so simple—in that order of difficulty. The three things the beginner has to master are *co-ordination*, *timing* and *orientation*. But all these will become instinctive with practice.

Co-ordination simply means applying the right amount of control movement(s), single, or together as required (mostly together in controlling aircraft). Beginners invariably tend to over-control, with excessive transmitter stick movements and take a little time to appreciate that control response is *proportional*. In other words a required control position should be selected by moving the stick *smoothly* to that position, not overshooting and having to correct with opposite movement. The full-size pilot flying an R/C aircraft for the first time, on the other hand, will probably *under-control*. (And the same with car drivers when first operating R/C cars). This is because models move faster than scale speeds, and also react much more rapidly to control movements or disturbances upsetting their course.

Timing is equally important. Because the person in control is separated from the model—and in the case of aircraft often by an appreciable distance—there tends to be a time-lag between appreciating what is happening to a model and what action is wanted at the controls. This applies both when putting on and taking off a control. But timing is usually the least difficult thing to master.

Orientation is a problem because when a model is moving *away* from you control response is natural, but when it has turned around and is *approaching* you head-on, right is left and left is right as far as the model is concerned. So you have to think in terms of reversed control movements for turning—stick to the right to make the model turn left, and vice versa. The trick is to think in terms of *being aboard* the model, not as an observer standing at a fixed point. This is not as difficult a knack to master as might appear at first sight. The ability to react as if aboard the model is most important when controlling aircraft; and particularly so in the case of aerobatic models when it comes to mastering inverted flight where *all* flight controls are reversed in response.

If it seems formidable to master these basic requirements, it is *not*, provided the initial approach is not too ambitious (*see* Chapter 2). Obviously some individuals will learn faster than others, and become more proficient with more advanced types of models. Equally obvious, anyone who can ride a bicycle has a natural ability to master co-ordination and timing—and will soon also master orientation when it comes to a radio-controlled model.

Radio Trouble-Shooting

The most common cause of *genuine* radio failure is flat batteries (either Tx battery, Rx battery, or both).

The most common cause of *claimed* radio failure is 'pilot error' (particularly in the case of aircraft); and second a poor radio installation and control hook-up which could never hope to work properly any way.

Modern radio-control transmitters, receivers and servos of reputable brand name are very reliable, but of course not completely foolproof or fault-free, and certainly not proof against abuse. Here, though, it is surprising how often the receiver and servos can withstand an aircraft crash which badly damages the model but still leaves the radio in working condition.

OPERATING RADIO CONTROLS

Following are the faults which may occur with the radio side, causes and remedial treatment to take:-

Set does not work when switched on

1. Check that both transmitter *and* receiver are switched on.
2. Check that all plug-together connections are completed properly (battery lead and servo leads plugged into the receiver).
3. Check the voltage of both the Tx and Rx battery. Recharge (or replace in the case of drycells) if not giving full specified voltage (*see* Chapter 13).
4. With drycell sets, check that the battery box connections are clean and making good contact with the cells.
5. Check that both the transmitter and receiver crystals are in place and they are of the same colour code (i.e. a properly matched pair).
6. Fractured wires in wiring harness.

Set switched on. Servos move

If the receiver is switched on first, the servos may move momentarily and stop; then move again and stop when the transmitter is switched on. This is normal.

If the transmitter is switched on first, then the receiver, the servos may move and stop. Again this is normal.

Note: The generally recommended procedure is always to switch the *transmitter* on first, then the receiver. This will prevent malfunctioning of, and possible damage to, the servo(s) if there is a strong spurious signal already present on the same frequency (e.g. from another transmitter).

When switching off the reverse applies for similar reasons. Switch the *receiver* off first, followed by the transmitter.

Set switched on. Servos continue to move

There are three most likely causes.

1. Transmitter too near receiver, swamping it with signal. Move the transmitter several feet away to check.
2. Unmatched crystals. Check that the Tx crystal and Rx crystal are a correct match.
3. Interference from somewhere. Switch off the transmitter. If the servos still continue to move, then suspect interference. Wait and try again later to see if the interference has disappeared.

4. Possible receiver fault, but eliminate 1, 2 and 3 above first before suspecting this.
5. If only one servo moves, possible receiver *or* servo fault. Check servo plug pins for damage.

One Servo fails to respond

This can be checked by substitution. Unplug that servo and plug in another servo which is working into that receiver outlet. If this servo works, then the first servo is faulty. If the substitute servo does not work, then the receiver circuit to that outlet is faulty.

Note: It is often possible to continue operation in the field even when a servo does fail by 'sacrificing' one control. Unplug the non-working servo and re-allocate the remaining servos to the control functions which will still keep the model operational. For example, on aircraft you could 'sacrifice' aileron control; or on a boat, motor control in favour of rudder.

Servos become progressively slower in operation

1. All servos affected:

This is most likely due to a failing receiver battery, particularly a dry battery where voltage falls gradually with operating time. With a Nicad battery, servo operation is more likely to cut off completely as the battery approaches its fully discharged condition.

2. One servo only affected:

This is most likely to be due to a binding control movement. Check this out first; but check battery condition as well.

Servo operation becomes erratic

Likely causes:

1. Failing Rx battery *or* Tx battery (the latter producing lack of range).
2. Interference.

Servos have momentarily involuntary movements

This is called *glitching* and the usual cause is interference. Check also for possible bad connections on the servo plug pins and receiver socket.



The most difficult subject of all for radio control is a model helicopter. The mechanical system involved is highly complex and the pilot has virtually to fly the model all the time. In the hands of real experts, though, (some) R/C helicopters can be looped and even flown inverted.

Lack of Range

1. Failing Tx battery and/or failing Rx battery.
2. Inefficient receiver aerial—aerial wire coiled up or cut short, rather than being stretched out straight.
3. Transmitter aerial not fully extended, or not properly attached to the transmitter.
4. Limitations of operating site. Some areas surrounded by modern buildings with a high metal content, metal sheds, and even high wire fences, can drastically reduce the operating range of model radio-control equipment.

As a general rule, with fresh batteries, the range of modern radio-control sets should be more than adequate. Typically this is at least $\frac{3}{4}$ –1 mile ground-to-air for controlling aircraft. At this distance the model is too small to follow its path properly anyway, so it should not

be flown to such an extended range. Ground-to-ground range when operating boats or cars is appreciably less, but normally at least 300–400 yards.

If in doubt about the range capabilities of your set, operating from a particular site, carry out a range check. In the case of aircraft, get an assistant to carry the model away into the distance until the receiver no longer responds to the transmitter signal (hand signals can be used for communication). This will give the extreme ground-to-ground range. Ground-to-air range with the model in flight should be at least four times greater.

Carrying out a range check with boats, the boat should be in the water and the *transmitter* carried away into the distance to check range.

One tip to remember. Maximum range will be obtained when the transmitter telescopic aerial is angled upwards and roughly at *right angles* to the model. Pointing the tip of the aerial *towards* the model will *reduce* the effective range.

Chapter Thirteen

BATTERIES

FLAT BATTERIES are the most common cause of radio failure. That makes it an *essential* requirement for reliable operation to *make sure* that the Tx and Rx batteries are fresh, or fully charged, at the start of any operating session. And that is not quite as easy as it may seem.

The *Transmitter battery* is usually 12 volts—either eight AA size dry cells or a 10-cell Nicad battery; or 9.6 volts (an 8-cell Nicad battery). (Some small transmitters may have lower voltage batteries). It is housed inside the transmitter case and not readily accessible for measurement of battery condition with a meter. Most transmitters have a simple meter on the face of the transmitter to indicate battery condition. With fresh batteries the needle should move to the far end of the 'green' position when the Tx is switched on. Theoretically at least there is ample battery power remaining as long as the needle remains in the green sector.

Normally with a Combo the transmitter battery is of a size (capacity) capable of giving a longer operating time than the standard receiver battery supplied with the Combo. Battery consumption when the transmitter is switched on is constant, regardless of whether a control is being operated or not. Typical current drain is of the order of 125–150 milliamps with a 4-channel transmitter, giving a normal operating time of 3–4 hours with a 450–500 mAh capacity battery.

Actual current drain will vary with different makes of transmitters—and also with the number of channels. If it is intended to use the transmitter for long periods at a time, it is worthwhile to carry out a bench check, leaving the transmitter switched on and seeing how long it takes for the battery condition indicator to fall to the red sector. Some manufacturers offer alternative 1000 mAh transmitter battery packs for more prolonged operation. With others it may be difficult, or impossible, to get a larger transmitter battery in the case.

Drycell Transmitter Batteries

With *drycells*, battery voltage falls slowly and continuously as the cells discharge. This will be indicated by movement of the battery

condition indicator towards the red zone. Reliable operation is no longer guaranteed when the needle enters the red zone.

It is important that the *drycells* be replaced at this stage. After a rest, if the transmitter is switched on again with the same batteries, the needle will probably show well up in the green zone. It has apparently recovered more life. But its voltage will fall very rapidly into the 'red' zone if used for a further session of transmission. In fact, do not start operating a drycell transmitter unless the battery condition indicator needle is well towards the top of the green on the scale.

Always use HP type drycells. These are more expensive than ordinary (SP) drycells but will last longer and be more reliable. They are also less liable to leak and cause corrosion damage in the set if left in the set in a discharged condition. Better still, use *alkaline batteries*, although these are much more expensive. At the level of current drain likely they should last four or five times as long as HP drycells. (See later notes on alkaline-manganese batteries). But always remove drycells completely if the transmitter is not likely to be used for two or three weeks. *Then always refit new batteries.*

Nicad Transmitter Batteries

Apart from being rechargeable, Nicad (nickel-cadmium) batteries behave differently to drycells. They are capable of sustaining a higher current drain and have a longer life (capacity), size for size. Unlike a drycell battery, too, they generate a substantially *constant voltage* which is maintained until the battery is almost fully discharged. Then the battery voltage drops quite suddenly.

This means that the battery condition indicator needle will stay in about the middle of green right until the end of the useful battery life and then move into the red quite rapidly with little or no previous warning. The only real safeguard against battery failure is to start with a *fully charged* Nicad and restrict operating time to less than the known 'duration' of the battery.

Unlike drycells, Nicad transmitter batteries can be left *in situ*, regardless of their state of charge. They will not come to any harm, even if left for long periods in a discharged state. Most transmitters using a Nicad battery have a built-in connection between the battery and a socket on the side of the case into which a charging lead can be inserted to recharge the batteries. Basically, therefore, a Nicad transmitter battery never needs removing at all, unless accidentally damaged by a drastic overcharge.

BATTERIES

Deciding the length of charge required for a Nicad battery is not a quite straightforward subject, however—see later notes on *Battery Charging*.

In general discharge times with standard size Nicad batteries are adequate for normal usage of radio-controlled models over one or more sessions. The limiting factor for operating time is usually the receiver battery capacity.

Receiver Batteries

Receivers commonly work off a 6-volt battery (four 1.5 volt AA size) or a 4.8 volt battery (a 4-cell Nicad battery). This battery supplies both the receiver *and* the servos. The servos draw by far the most current and battery duration is very dependent on how frequently the servos are operated. Battery life can be extended by using low current drain servos, which type should be regarded as *essential* for use with a *drycell* receiver battery.

Better Dry Batteries

The equivalent AA size (HP7) drycell is also available in an *alkaline-manganese* battery giving the same cell voltage (1.5 volts) with a much greater capacity for the same physical size. It also has a more constant discharge voltage with a capacity for meeting high current demands.

Unfortunately the cost of this type of battery is considerably higher than an HP drycell, and it is not rechargeable. On economic grounds, therefore, it is not always a practical alternative to use. However alkaline-manganese batteries could provide a means of making an all-drycell outfit *usable* under circumstances where the life of HP type drycells proves unacceptable and where cost was not immediately important, particularly as they will fit in the same battery box. Change to a rechargeable Nicad battery would be a better long-term proposition, though, and much cheaper in the long run.

Battery Capacity

The *capacity* of a battery is a measure of its stored energy, quoted in terms of amp-hours—or, in smaller size batteries, in milliamp-hours (mAh). What this figure means is that battery life is given by dividing its capacity rating by the current being drained from it. For example, if the battery capacity is 225 mAh and it is subject to a continuous current drain of 25 milliamps, its life would be $225 \div 25 = 9$

hours. Equally at 50 mA current drain it would be 4½ hours; or at 100 milliamp drain, 2¼ hours.

In practical use, whilst the current drain of a Tx battery will be constant, that of the Rx battery will vary. In the case of a receiver it could vary from as little as 10–15 mA with the receiver ‘idling’, up to as much as 250–300 mA when three servos are being operated simultaneously (see Chapter 5). Battery life can, therefore, only be estimated on an average current drain basis (and will be modified if actual usage is above or below average).

Nicad batteries have a specific capacity charging, related to their construction and physical size. All rechargeable batteries, in fact have specific capacity figures.

Unfortunately in the case of carbon-zinc type batteries (HP7, etc.) it is impossible to establish capacity figures, even nominally. The *effective* capacity will vary *with* current drain and *with* actual period(s) of use. So battery life can only be determined by actual tests at specific current drain values *and* on-off times.

The *alkaline-manganese* battery mentioned above as a ‘substitute’ for drycells is interesting in this respect for it *does* have a specific capacity figure. In fact, for an AA size all this is 1500 mAh, or considerably higher than the capacity of the usual type of Nicad used as a receiver battery. A Nicad cell of similar physical size (AA size) still only has a capacity of 450–600 mAh. It is unfortunate that the alkaline-manganese battery is so expensive!

Recharging Nicad Batteries

The optimum charging rate for most Nicad batteries is at a current of 1/10th the Ah capacity, e.g. 22.5 milliamps for a 225 mAh capacity battery. *Time* to give a full charge, starting with the battery in a discharged state is then 15 hours.

Chargers supplied with all-Nicad Combos are normally designed to charge at optimum rate, equivalent to a full-charge time of 15 hours. The fact that it is impossible to determine the actual state of charge of a Nicad is not particularly important. (Measurement with a voltmeter would show a voltage of 1.2 volts per cell, or slightly higher, with the battery in any state except when virtually fully discharged). A 100 per cent overcharge, i.e. charging for twice the time really needed—will do no harm *at the 1/10th charge rate*.

Thus with both the Tx and Rx battery, even if known to be only partly discharged, a 10-hour charge will be quite safe. If suspected to

BATTERIES

be more completely discharged, or the set has not been used for some time, a full 15 hours charge should be given.

Some modellers adopt a 'rule of thumb' method for recharging, calculating recharge time needed (at the 1/10th rate) as *twice* the time the radio has been used during a day's operating session. Thus if the radio was used for, say, six 20-minutes periods, a total of 2 hours, a recharging time of $2 \times 2 = 4$ hours should bring the batteries back to a fully charged condition. This rule works well except for the fact that when not in use Nicad batteries will continue to lose charge equivalent to a loss of capacity of about 10 per cent or more per month.

For this reason, it is always advisable to recharge batteries immediately prior to contemplated use—say the day before, or overnight. Working on the 'rule of thumb' basis for calculating charging time required, an additional charging time is needed to make up the loss from standing idle after the previous period of use. Again a 'rule of thumb' figure for this is an additional 2 hours charging time for every week of idleness, which should be more than adequate. However, any *total* charging time calculated on this basis should not be greater than 15 hours. (The full time required to recharge a fully discharged Nicad at the 1/10th rate).

It is quite easy to check that a transmitter Nicad battery is fully charged. When switched on the needle of the battery condition indicator should 'click' immediately to the top of the green section as soon as the set is switched on. It will move down into the green section when the set is used for some time as the initial fully charged voltage (about 1.3 to 1.4 volts per cell) drops to a constant 1.2 volts per cell or load after a short period.

It is not so easy to check the receiver Nicad battery voltage. This is usually a pre-wired battery pack, terminating in a socket (taking the plug in the wiring harness). It is impossible to 'tap' the socket connections with the probes of a voltmeter. If you do want to make a meter check it is best to unplug the battery and insert a spare plug with cut-off leads, then connect the voltmeter to the bared ends of two out of the three wires. Trial and error will show which of the two wires are the right ones to use.

Rapid Charging

Through forgetfulness to put the batteries on charge the previous day—or even forgetting to leave the charger switched on overnight—you may be faced with uncharged batteries when you want to start an

operating session. Now quick-charging of Nicads is quite possible. There are rapid chargers available which recharge Nicads in less than a quarter of an hour or so, even in the field, working off an ordinary car battery. *But this applies only to vented Nicads.* Many of the Nicads supplied with Combos are not vented and *no attempt should be made to charge them at high rates with a quick charger* unless the manufacturer's instructions implicitly state that this can be done in an emergency. If *non-vented* Nicads are quick-charged they are liable to overheat and be permanently damaged *or even explode.*

Specifically the round button-type Nicad cells are *not* vented, and so must *never* be rapid-charged. Cylindrical type Nicad cells *are* vented, but this is only a basic safety measure to accommodate accidental overcharge at normal charging rates. They are not *necessarily* suitable for *rapid* charging, unless specifically stated to be so.

Exactly the same considerations apply if you use a charger different from the one supplied with an all-Nicad Combo. Use one which will provide the same voltage output and charge at the 1/10th hour rate. Nicad batteries are expensive, and so should be treated with consideration when recharging. Used properly they will continue to give satisfactory service through many hundreds of discharge/recharge cycles. They can be ruined by a single, drastic overcharge at excessive current rates.

If the type of Nicad battery used *is* vented and *is* specified as suitable for rapid charging, then a discharger/charger unit should be used for recharging rather than a straightforward charger. This will first enable the battery to be *fully* discharged safely, before being subject to a charge at a high current rate. Time of charge is *critical* and a unit fitted with an *auto timer* is recommended, so that it will switch itself off at the end of a set period and so prevent accidental overcharge.

Make it a Habit

If you operate radio-controlled models regularly, make it a habit to adopt a regular pattern for recharging the Tx and Rx Nicad batteries. Logically, give the batteries a 'full' (10–15 hour) charge the day before, or overnight. But you could forget.

Some modellers prefer to give batteries a full charge immediately after returning from an operating session—then, immediately before the next session give a 10 per cent 'top-up' charge, i.e. a one-hour charge. There should be time to do this on the same day, if you *have* forgotten to do it the night before.

Chapter Fourteen

SERVICING AND REPAIRS

THE RECEIVER AND SERVOS of a radio-control outfit should be regarded as 'little black boxes' which either work, or do not. If they do not, they should be returned to a *qualified service agent* who can locate and rectify the trouble. And 'qualified', here, means an experienced expert in *model radio control systems*, and preferably one who specializes in that type of set. He should then have any necessary replacement items ready to hand as well as a full working knowledge of the circuitry involved. Most leading brands of radio control equipment have their recognized service agents in the U.K. and sets can be returned to them direct, or through the local model shop from which the set was bought.

Some apparent faults may not be faults at all in terms of radio failure and there are a number of simple checks you can make to establish whether or not this is so—see 'Radio Trouble-Shooting' in Chapter 12.

Radio failure after crash damage

It is possible to check the receiver and individual servos by 'substitution', as described in Chapter 12. If this is not possible, or several units appear faulty, return the whole set for servicing, including the transmitter. The circumstances under which the damage occurred should also be described in brief detail and this can be of considerable assistance to the service engineer in establishing the source, and possible cause of the fault.

Remember, though, that probably ninety per cent or more of so-called radio faults causing a model aeroplane to crash are usually due to *pilot error*, or some failure in the 'mechanical' system—not radio failure. So be fair in your report. The servo engineer probably knows better than you what can go wrong through improper model preparation, lack of pre-flight checking—and mistakes made by hundreds of R/C model pilots!

After Extended use

The golden rule with radio is that as long as it is working properly,

leave it well alone. Transmitter, receiver and servos do not need taking apart for cleaning—but do keep dirt, oil, etc., from accumulating on the outside of the cases.

Provided nothing untoward happens—interference can be a particular problem at some sites, especially on 27 MHz operation—radio faults are comparatively rare. Some deterioration in the performance of servos can be expected, however, after an extended period of use.

This can be due to two causes—(i) dust or dirt collecting on the track of the feedback potentiometer; and (ii) wear on the gear train (normally wear on the spindle bearings) producing sloppy movement. The reasonably expert modeller can, in fact, tackle either of these faults himself, e.g. by fitting replacement parts in the servo case.

Routine Care

Do not unplug leads when not necessary. Plug pins are delicate and easily damaged, and dirt can get on to unplugged plugs and sockets. Most receiver wiring harnesses incorporate a 'bare' socket for plugging in the charger for the Rx Nicad battery, so you do not even have to remove the battery for charging. (This feature is not incorporated in all makes of sets.)

Where you do have to unplug connections—such as the aileron servo lead on an aircraft to remove the wing—an occasional *light* spray of *contact cleaning fluid* contained in an aerosol can should be given to both plug and socket. Do *not* use WD40 or similar water-repellent fluid for spraying contacts, battery box springs, switches, etc, and never spray printed circuit boards with this type of fluid.

Servo mounting and linkage movements should be inspected regularly. Check that servo mounting screws have not slackened, or mounting grommets displaced. Damage to servo arms or output discs is unlikely, and on plastic materials wear on the holes carrying the push rod end connections is unlikely. Wear can develop on holes in *metal* control horns or bellcranks—quite rapidly in the case of aluminium parts.

Exposed sockets on transmitter cases—usually only the battery charging socket—should be wiped clean before fitting a plug, and will benefit from an occasional spray with contact cleaning fluid. Some modellers also recommend similar treatment for the telescopic aerial, but this should not be necessary. If the aerial does get dirty or greasy, wiping it clean with a damp cloth and mild detergent solution should be enough.

Dirt and dust—and particularly oil or fuel—should be kept out of the open centre parts of the control stick mechanisms. *Never* oil these movements. This can only do harm—and attract dust. Brush and blow clean as necessary—the puffer-type brush used for camera lens cleaning is excellent for this purpose.

Apart from this the transmitter should only need a little ‘cosmetic’ treatment from time to time—wiping off dirt or greasy fingermarks, etc., with a damp cloth and mild detergent solution. Solvent type or ‘strong’ cleaning fluids should never be used, as these could attack the case material.

Be Careful with Crystals

The removable Tx and Rx crystals are precision components and should be handled with care when unplugging them, or plugging them in. They usually have a coloured paper tag attached to assist in pulling them out of their socket, but on some sets the crystals are mounted in plastic holders (which is better practice but makes a more clumsy fitting).

Crystals are not necessarily *perfectly* stable. Their ‘spot’ frequency can drift slightly with age, or due to exposure to undue heat, mechanical shock or other unfavourable causes. If ‘frequency drift’ is suspected, then they can be returned to the specialist service agent for checking, or replaced with a new pair for that particular ‘spot’.

Crystal frequency drift is seldom a noticeable problem with 27 MHz AM sets. Crystals for 27 MHz *FM* sets have to be more precise, so crystals for AM sets should *not* be used on FM sets, even if of the same specified frequency. Requirements for crystals for UHF (459 MHz) sets are even more critical and crystals supplied with or for UHF sets have usually been artificially aged to stabilize them. They are considerably more expensive to produce.

APPENDIX I. LEGAL REQUIREMENTS

UNDER LAW, any operator of a radio-control model can be held responsible for damages or injury caused to property or people. Third Party Insurance is thus a necessary requirement, particularly in the case of radio-controlled aircraft. For members of model clubs, and again for those taking part in organized competition for radio-controlled models, adequate insurance cover is obligatory. It is possible to arrange cover to be included in a domestic insurance policy. There is also a scheme specially for modellers sponsored by Model and Allied Publications (publishers of a range of model magazines) providing cover of up to £250,000 for an annual premium of £2. Acceptance under this scheme is dependent on placing a regular order for one or other of the MAP monthly magazines.

The operation of models in public parks, etc., is subject to local bye-laws and other local and national government restrictions. The operation of particular (or even all) types of models may be banned at some sites; or restricted in others. Specifically, too, it is now an overall legal requirement that all powered models should have suitably silenced engines so that the noise level they generate does not exceed 85 dB(A), measured at a distance of 15 metres.

Joining a club can be most helpful in these respects. It will be aware of any restrictions imposed by local bye-laws, know where and when radio-controlled models can be operated, and be in a position to negotiate through national bodies on the path of future legislation, etc. Many clubs also provide their own facilities for insurance.

No licence is required for the operation of model radio controls (since 1981) and so far as the modeller buying proprietary equipment is concerned all necessary regulations governing permitted operating frequencies, transmitter power and type of transmission have been taken into account by the manufacturers of the equipment. This does not necessarily absolve the modeller from responsibility should the equipment actually work in some 'illegal' manner.

APPENDIX II. MODEL RADIO-CONTROL FREQUENCIES

THE 27 MHz BAND is a standard frequency for model radio control used (legalized) by most countries in the world. In the U.K. it was the *only* frequency commonly used up to 1980, the number of modellers using 459 MHz UHF equipment still being quite small at that time, and with 35 MHz sets still to appear on the U.K. market. The 459 MHz UHF band, incidentally, is exclusive to the U.K. The only other recognized UHF band is 433 MHz, legalized in Austria and Belgium.

Legislation in countries outside the U.K. is more generous in allocation of radio-control frequencies to modellers; and the 27 MHz band is shared by other users. In Germany (and U.S.A.), for example, the 27 MHz band is also legalized for domestic use of walkie-talkies (Citizens Band radio). Because of the increased likelihood of interference to model radio control on this band, Germany, in fact, prohibits the use of 27 MHz for model *aircraft* control (although it is available there for boats and cars), and specifies the 35 MHz band for exclusive use by R/C aircraft. Another band also available for R/C modellers in Germany is 40 MHz.

Legalized bands for operating in other major countries are:—

Austria	— 13, 27, 35 and 40 MHz
Belgium	— 27, 32, 40 and 72 MHz
Canada	— 27, 53 and 72 MHz
Denmark	— 27, 35 and 40 MHz
Eire	— 27 and 35 MHz
France	— 27 and 72 MHz
Holland	— 27 and 40 MHz
Italy	— 27 and 72 MHz
South Africa	— 27, 53, 54 and 60 MHz
Spain	— 27 MHz
Sweden	— 27 MHz
U.S.A.	— 27, 40, 54 and 72 MHz

It should be noted that whilst it is possible to purchase equipment in this country with crystals for other than the 27 MHz or 35 MHz band (e.g. 32 MHz, 40 MHz, 54 MHz, 72 MHz) it is illegal to operate such equipment *in the U.K.* with such crystals fitted. It can only be operated legally in such countries where these particular frequencies are permitted for model radio control use.

APPENDIX III. 27 MHz SPOT FREQUENCIES

THE 27 MHz RADIO BAND is split into six main 'spot' frequencies for operating on, each spot being separated from its adjacent spots by 50 kilocycles. These specific spot frequencies are designed by a colour. Intermediate spot frequencies can also be used, with 25 kilocycles separation. These are called split frequencies and are designated by a two-colour combination.

Transmitter Crystal frequency MHz	Receiver Crystal frequency MHz	Colour
26.975	26.520	grey/brown
26.995	26.540	brown
27.025	26.570	brown/red
27.045	26.590	red
27.075	26.620	red/orange
27.095	26.640	orange
27.125	26.670	orange/yellow
27.145	26.690	yellow
27.175	26.720	yellow/brown
27.195	26.740	green
27.225	26.770	green/blue
27.255	26.800	blue

All 27 MHz sets will be suitable for working on any of the six main spot frequencies (single colours). Not all are suitable for working on all twelve spot frequencies, i.e. their circuits are designed to accommodate 50 kHz separation, but are not suitable to accommodate 25 kHz spacing without interference.

It is important that crystals used should be matched pairs supplied by the manufacturers of that particular Tx-Rx Combo. There can be slight variations in actual crystal frequency with those from different manufacturers.

It is the *transmitter* crystal frequency which governs the frequency of radio transmission. The matching *receiver* has a slightly lower frequency (usually 450 kHz less) necessary for 'superhet' working. A receiver *may* also work with a crystal having a frequency 450 mHz *above* the transmitter frequency, but this can cause interference problems and even illegal operation of the equipment. It is thus important to operate only with a matched pair of crystals.

27 MHz SPOT FREQUENCIES

Note: It is an unwritten law (if not obligatory under club rules if you are a member of a model club) that when operating in company with other radio control modellers you should clearly display the spot frequency on which you are operating.

In the case of 27 MHz radio, this is done by attaching a coloured pennant, tab or other marker corresponding to the spot frequency to the transmitter aerial.

With UHF radio there are no colour codes for spot frequencies and so a marker showing the *channel number* is displayed on the transmitter.

35 MHz SPOT FREQUENCIES

Spot frequencies for the 35 MHz band (allocated for the use of model aircraft controls only from January 1981) are designated by numbers, starting from channel 61 (35.010 MHz) up to channel 80 (35.200 MHz). This embraces 20 channels in all within the band at 10 kHz spacing (i.e. at a much closer spacing than that employed in the 27 MHz band).

APPENDIX IV: U.K. FREQUENCIES AND THE FUTURE

THERE IS NO DOUBT at all that the 27 MHz band allocated for model radio control in the U.K. is overcrowded with users. It is not an exclusive band. It is shared legally by other users and, until late 1981, illegally by users of walkie-talkie and Citizen Band (CB) radio. Prior to the Government's decision to legalize the operation of CB radio in late 1981 the transmission of *speech* was not permitted on the 27 MHz band in the U.K.

Interference to model radio-control operation can be quite a problem in some areas, and in others comparatively rare. The position is likely to get worse with the legalization of CB radio, particularly as some such sets are likely to be (illegally) operated at high power outputs and thus present interference to other 27 MHz users over a wide range. Obviously, too, CB interference on 27 MHz will be most prevalent in urban and city areas, and in the proximity to main highways. The position is not a satisfactory one as far as the radio-control modeller is concerned and may take years to resolve, if at all.

Most other countries have made alternative frequency bands available for model radio control (*see* Appendix II). Germany in particular recognized early the potential danger of interference to model aircraft radio control and legalized the 35 MHz band exclusively for R/C aircraft. (For somewhat dissimilar reasons the United States prohibits *FM* transmission on the 27 MHz 'model' band).

From 1981 a further frequency band (35 MHz) has been made available for U.K. operators, specifically intended for *model aircraft* controls. The 27 MHz band (and 459 MHz) remains available for R/C aircraft, boats and cars (and any other type of radio-controlled model).

The 35 MHz band is to be 'split' by 10 kHz spacing, which represents a fairly demanding specification. As a result simple 'conversion' of 27 MHz equipment to 35 MHz working may not be practical with much existing 27 MHz equipment which may have been designed originally for 25 kHz (or even 50 kHz) spot frequency spacings. Modification to change the operating frequency from the 27 MHz to the 35 MHz band is relatively simple (basically just a change of crystal), but a much cleaner signal is necessary to work with 10 kHz

U.K. FREQUENCIES AND THE FUTURE

spot spacings. This could call for extensive—and expensive—modification of the transmitter circuit. Conversion of the 27 MHz receiver to 35 MHz working with 10 kHz spacing could be even more difficult—and even call for a complete re-design of the receiver circuit.

It should be noted, however, that the introduction of 35 MHz working does not render all 27 MHz sets obsolete. They are still the standard for radio control of model boats and cars, and can still be used for aircraft.

INDEX

- AA Cells, 41, 54, 117, 118
- Aerial, 9, 28
- Aerial photography, 26, 98 *et seq.*
- Aerial survey, 106
- Aerobatic manoeuvres, 63-65
- Aileron controls, 87
- Ailerons, 20, 25, 62, 91-93
- Airbrakes, 25, 60
- Alkaline batteries, 40, 116
- AM, 12, 59
- Antenna, — *see* Aerial,
- Auxiliary sailplane, 18

- Batteries, 39
- Battery capacity, 39, 117 *et seq.*
- Battery charging, 118 *et seq.*
- Battery condition indicator, 33
- Battery leads, 37
- Bellcrank, 87, 88
- Boat installation, 79
- Boat rudder movement, 90
- Bomb dropping, 26
- Brand names, 57, 60
- Buddy box, 18, 35

- Camera, 99-101
- Camera focus, 102
- Camera operation, 26
- Capacity, 39, 117 *et seq.*
- Car installation, 80, 81
- Cars, 22, 57
- Channels, 13, 24
- Chargers, 115 *et seq.*
- Charging Nicads, 118 *et seq.*
- Citizens Band (CB), 13, 37, 59, 128
- Cleaning fluids, 121-122
- Clevis, 85
- Clubs, 17, 23, 124
- Colour coding, 127
- Combos, 9, 13, 24, 54

- Complete outfits, 10
- Control linkages, 85
- Control mixing, 67 *et seq.*
- Control movements, 89, 90
- Co-ordination, 109
- Coupled controls, 91 *et seq.*
- Crash damage, 121
- Crystal colour coding, 126
- Crystal stability, 123
- Crystals, 11, 123
- Current consumption, 115

- Decoupling, 91, 96
- Differential ailerons, 87
- Dihedral, 25
- Drycell, 8
- Drycell batteries, 39, 115
- Drycell combo, 54
- Dual-rate switching, 67

- Electric boats, 21, 56
- Electric cars, 22

- Fast boats, 21
- Fast electric boats, 26
- Fast electrics, 57
- Faults, 111 *et seq.*, 121-2
- Feedback, 44, 45, 51
- Films for aerial photography, 108
- Flaps, 26, 95
- FM, 12, 59
- Frequencies, 11
- Frequency colour coding, 127
- Frequency module, 73
- Frequency pennants, 14, 127
- Full house, 25, 55, 94
- Functions, 13

- Gaiters, 79
- German regulations, 59

INDEX

- Gliders, 18, 29, 56, 79
- Hesitation rolls, 71
- High speed boats, 56
- Hovercraft, 21
- HP batteries, 40
- HP cells, 116, 117
- Instructor, 17, 35
- Insurance, 124
- Interference, 12, 111
- Japanese productions, 58
- Jib-twitching, 27
- Joggled bend, 84
- Joystick, 28
- Keeper, 84
- Kits, 8
- Legal requirements, 124
- Legalized bands, 125
- Lenses for aerial photography, 102
- Licence, 16, 124
- Life of servos, 46
- Linear servos, 43, 83
- Manufacturing faults, 61
- Meters, 33
- MHz, 11
 - 13 MHz, 125
 - 27 MHz, 13, 15, 124, 128
 - 35 MHz, 13, 16, 125, 127, 128
 - 40 MHz, 125
 - 60 MHz, 125
 - 72 MHz, 125
 - 459 MHz band, 13, 16
- Micro servo, 48
- Mini servo, 48
- Mixing, 67
- Mode 1, 31
- Mode 2, 31
- Model clubs, 17, 23
- Model shops, 17
- Models for aerial photography, 98, 99
- Modules, 37, 73
- Motorcycles, 23
- Mounting cameras, 104-105
- Muffs, 36
- Murphy's law, 7
- Neckstrap, 35, 36
- Neutral adjustment, 88
- Nicads, 8, 39, 41, 54, 116-117
- Non-proportional, 99
- Non-proportional control(s), 14, 33, 50
- Operating times, 39, 40
- Orientation, 109, 110
- Output movements, 49
- Parachute dropping, 26
- Paralleled servos, 92, 97
- Pilot error, 121
- Plugs and sockets, 9, 37
- Polythene bag, 80
- Positioning of components, 74 *et seq.*
- Potentiometer, 44, 45, 47, 51
- Powerboats, 21, 26
- Powered aircraft, 18, 19, 25, 56, 74
- Proportional controls, 10, 14, 26, 44, 50
- Pushrod, 80, 83
- Range, 28, 113, 114
- Rapid charging, 119
- Ratchet braking, 30
- Receiver current drain, 37-39
- Receiver mounting, 74, 75
- Receivers, 8, 37 *et seq.*
- Recharging batteries, 118 *et seq.*
- Remote potentiometer, 47
- Resolution, 44, 47, 51
- Retract servo, 49, 94
- Retractable undercarriage, 26
- RF Output meter, 34
- Rotary servos, 43, 49
- Routine care, 122
- Rudder, 20, 25
- Rx crystals, 11, 37, 126
- Rx current drain, 37, 38, 39
- Sailplanes, 18
- Sail winch, 26, 29, 42, 52
- Scale cars, 22
- Secondary controls, 26
- Separation, 126-127

INDEX

- Servicing, 59, 121 *et seq.*
- Servo current drain, 38, 39
- Servo faults, 112
- Servo mounting, 76 *et seq.*
- Servo movements, 49, 80
- Servo reverse switching, 67
- Servo reversing, 82, 83
- Servo substitution, 112
- Servo tape, 77
- Servo trays, 47, 78
- Servos, 9, 13, 14, 43 *et seq.*, 74
- Shock links, 94
- Sizes of servos, 48
- Snakes, 86
- Snap rolls, 62
- Spares, 59, 121
- Speed controllers, 52
- Split frequencies, 15, 126
- Spoilers, 25, 60
- Spot frequency, 11, 15, 109, 125, 127
- Stall force, 51
- Steerable nosewheel, 93
- Sticks, 28, 69
- Strip ailerons, 87
- Superhet, 11
- Telescopic aerial, 28, 122
- Throttle control, 25
- Throttle left, 19, 21
- Throttle right, 31
- Torque, 51
- Trainers, 18, 19, 55
- Transit time, 49, 50
- Transmitter, 8
- Transmitter cases, 34
- Transmitter trays, 35
- Trays, 47, 78
- Trim controls, 32, 62
- Trouble shooting, 110 *et seq.*
- Twist-grip throttle, 62
- Tx batteries, 115
- Tx crystal, 11, 126
- Tx current drain, 115
- UHF, 13, 59
- Undercarriage steering, 93
- US regulations, 59
- Vented Nicads, 120
- Voltages, batteries, 115
- Walkie-talkies, 128
- Wheel steering, 30
- Winch, 26
- Wiring harness, 7
- Yachts, 21, 26, 57

(continued from front flap)

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